SHARP

PROCEEDINGS

4TH ANNUAL COMMERCIAL AND PLASTIC COMPONENTS IN MILITARY APPLICATIONS WORKSHOP

Sponsored By:

SHARP
Sustainable **H**ardware and **A**ffordable **R**eadiness **P**ractices Program
Crane Division, Naval Surface Warfare Center
Crane, Indiana

15 & 16 November, 1995
The Westin Hotel
Indianapolis, Indiana

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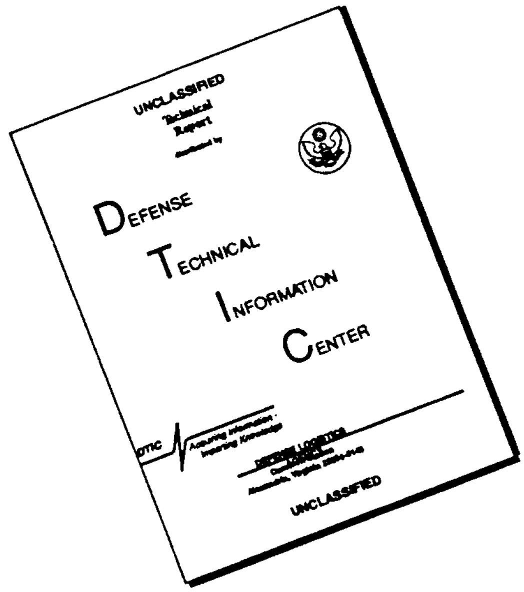

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COMMERCIAL & PLASTIC COMPONENTS IN MILITARY APPLICATIONS WORKSHOP

Westin Hotel
Indianapolis, Indiana

Agenda

Session 1 - Wednesday, 15 November, 1995

8:00-8:30	Registration, Continental Breakfast
8:30-8:35	Welcome; Dan Quearry
8:35-8:50	SHARP Introduction; Don Schulte, NSWC Crane

Plastic Package Availability Program - Final Review

8:50-8:55	PPA Program Introduction; Dan Quearry, NSWC Crane
8:55-9:55	PPA Overview; Ron Kovacs, NSC Program Manager
9:55-10:15	High Lead Count Testing & Chip Seal; Rob Camilletti, Dow Corning Summary of the Plastic Package Reliability Test Program; Bob Byrne, National
10:15-10:30	Break
10:30-11:30	Plastic Molding Compounds; Nick Rounds/Bill Bates, Plaskon
11:30-12:15	Sensor Chip Development; Dave Peterson, Sandia National Lab
12:15-1:00	Lunch
1:00-1:30	Low Lead Count Testing and Results; Dan Quearry, NSWC Crane
1:30-2:00	Low Lead Count F/A; Jim Reilly, USAF-Rome Lab
2:00-2:30	High Lead Count Testing & F/A; Ron Kovacs, NSC
2:30-2:50	Break
2:50-4:30	PEM Usage in Commercial Avionics; Fred Malver/John Fink/Bruce Johnson, Honeywell CFS
4:30-4:45	Summary & Analysis of the Honeywell Field Reliability Program; Bob Byrne, National
4:45-5:00	Conclusions and Future Work; Ron Kovacs, NSC
5:00-5:10	Days Wrap-up; Dan Quearry

COMMERCIAL & PLASTIC COMPONENTS IN MILITARY APPLICATIONS WORKSHOP

Westin Hotel
Indianapolis, Indiana

Agenda

Session 2 - Thursday, 16 November, 1995

8:00-8:30	Registration, Continental Breakfast
8:30-9:10	Summary Report, Commercial ICs in Military Systems Cliff Schwach, Rockwell
9:10-9:50	Best Commercial in Military Semiconductors Buf Slay, Texas Instruments
9:50-10:30	Transitioning From Military to Commercial Manufacturing Maurice Chenier, Computing Devices International
10:30-10:40	Break
10:40-11:20	Plastic Packaging Consortium TRP Dr. Luu Nguyen, National Semiconductor
11:20-12:00	The Reliability of Plastic Encapsulated Microcircuits William Denson, Reliability Analysis Center
12:00-1:00	Lunch
1:00-1:40	Long Term Storage of PEMs Bill Garry, Westinghouse
1:40-2:20	Accelerated Testing for Telecommunications Equipment Dr. Tony Chan, AT&T
2:20-2:40	Break
2:40-3:20	Plastic Package Total Dose Study Steve Clark, NSWC Crane
3:20-3:30	Days Wrap-up; Dan Quearry

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SHARP COMMERCIAL & PLASTIC COMPONENT
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15 & 16 November 1995

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SHARP

Sustainable Hardware & Affordable Readiness Practices

MR. DON SCHULTE
SHARP PROGRAM MANAGER
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SHARP

SHARP Program

Sustainable Hardware & Affordable Readiness Practices

6.3 Advanced Development Core Program

Align with Major Warfare Areas

to

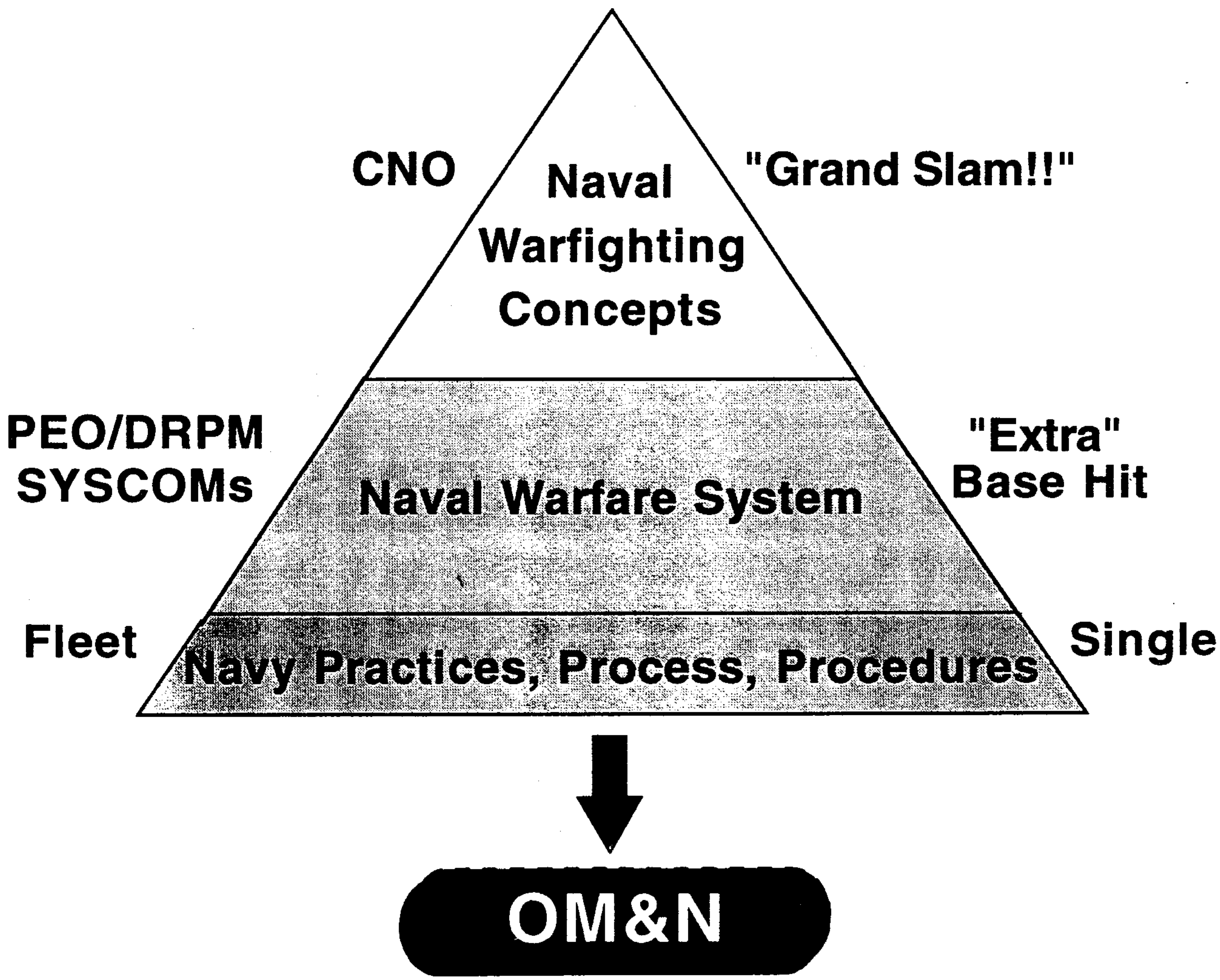
Facilitate Transition of Exploratory Development (6.2)

to

System Acquisitions on a Continuing Basis

Navy's Generic Logistic R&D

Navy R&D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Concepts
"Grand Slam!!"
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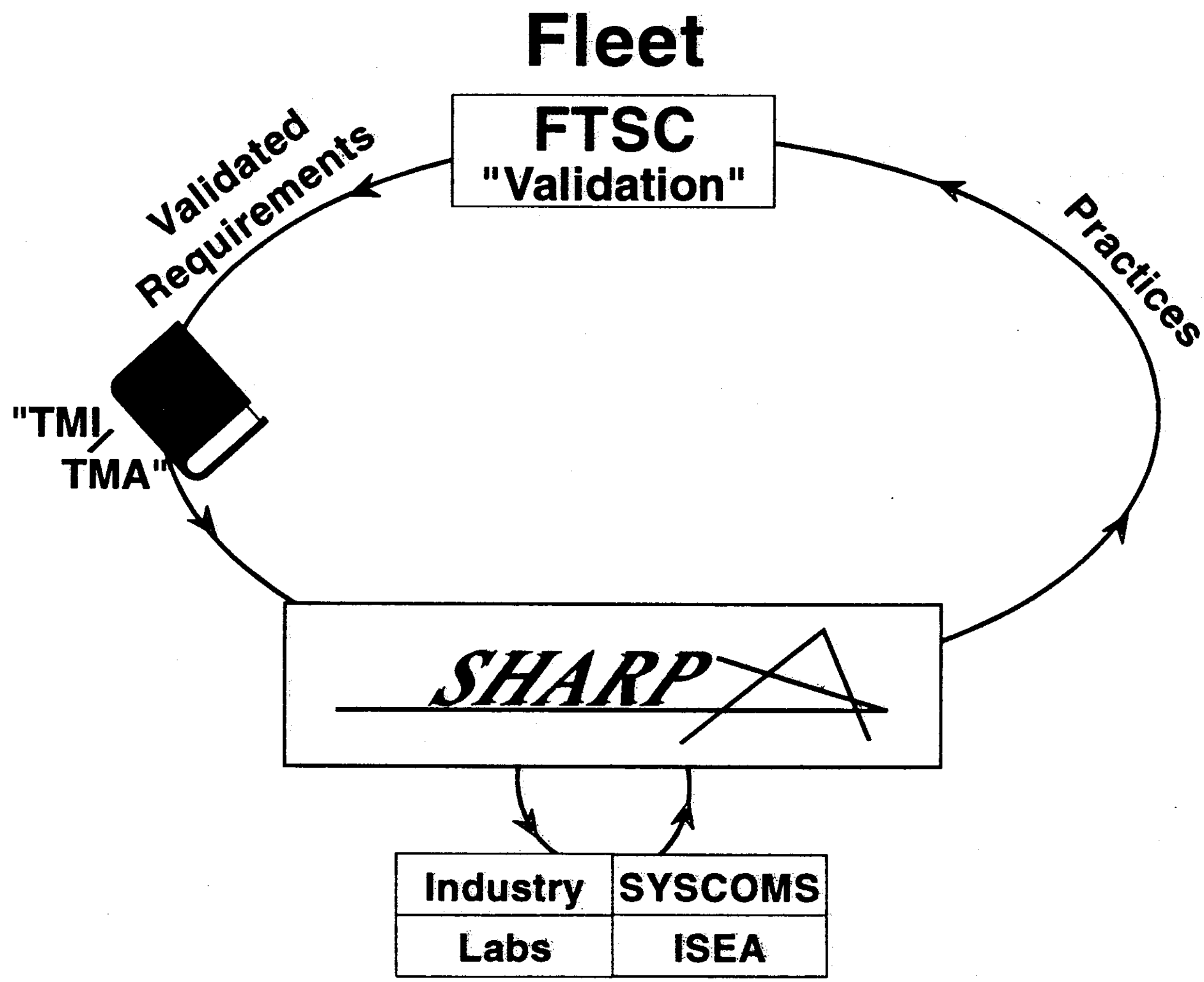
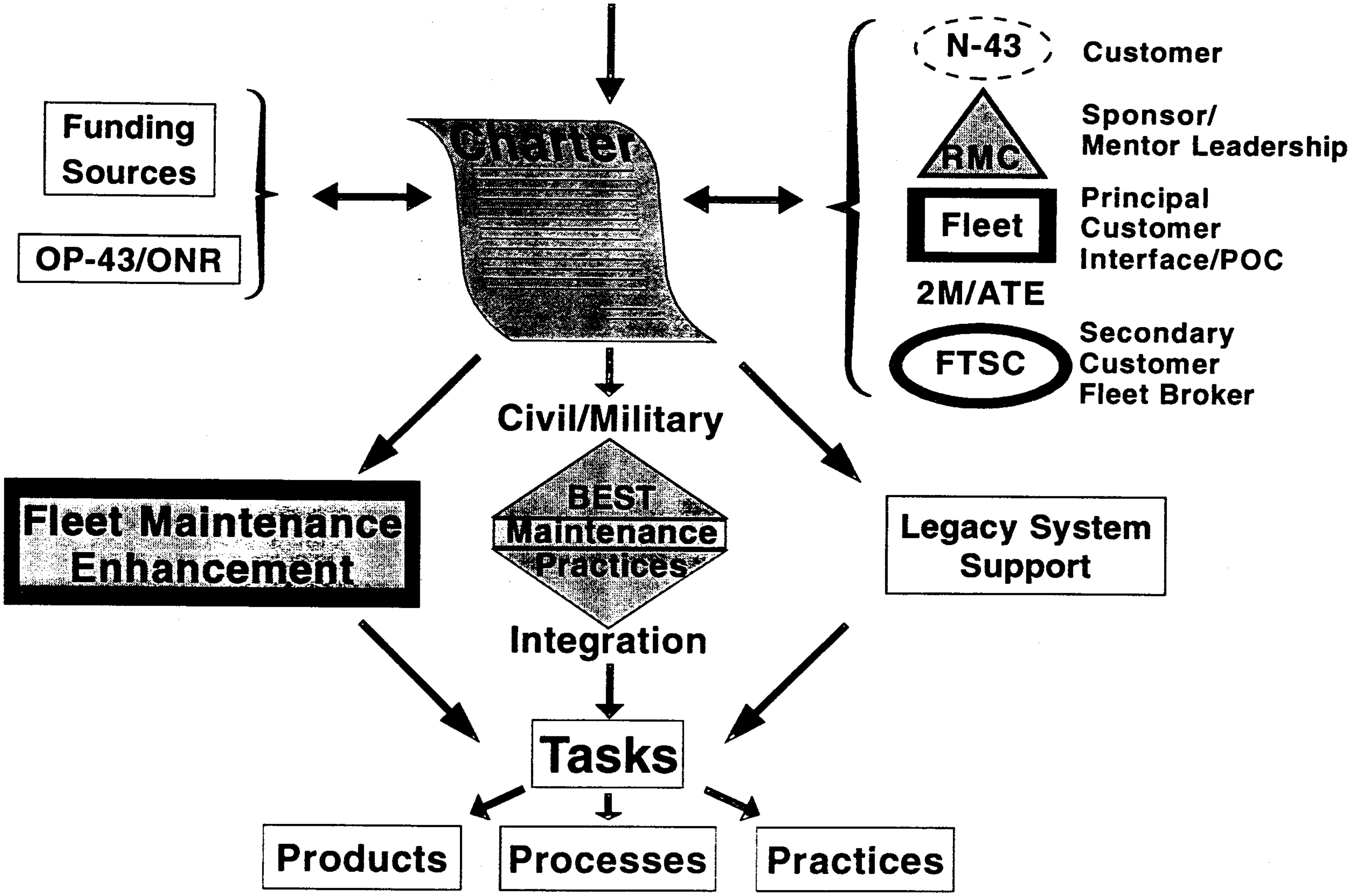


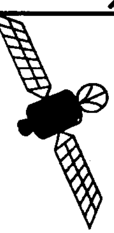
Enhanced Fleet Maintenance

(SHARP)
Sustainable Hardware & Affordable Readiness Practices



SHARP

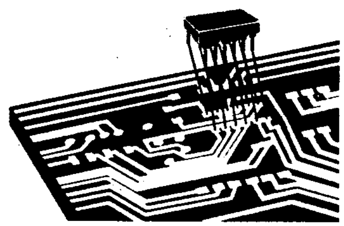
Legacy Systems



DMS

Technology Insertion

Commercial Product Insertion



Up-Grades

Reverse Engineering

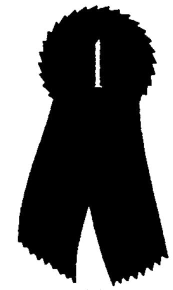
Re-Design

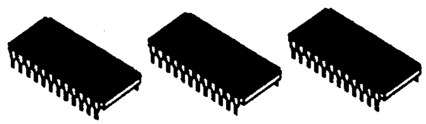
Recertification

SHARP

Civil/Military Integration

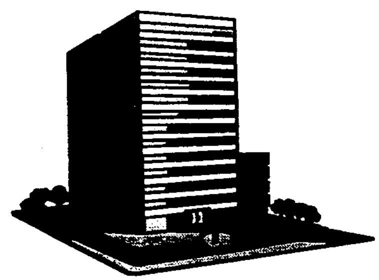
Best Maintenance Practices



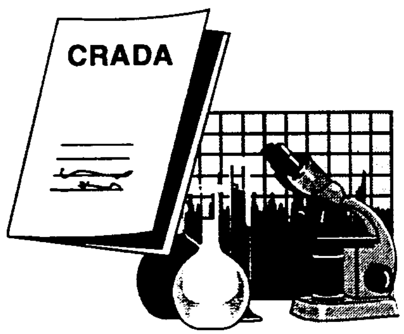


Commercialization

Standardization

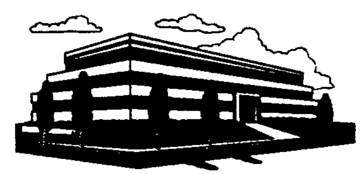


Privatization



Cooperative Research

National Centers of Excellence

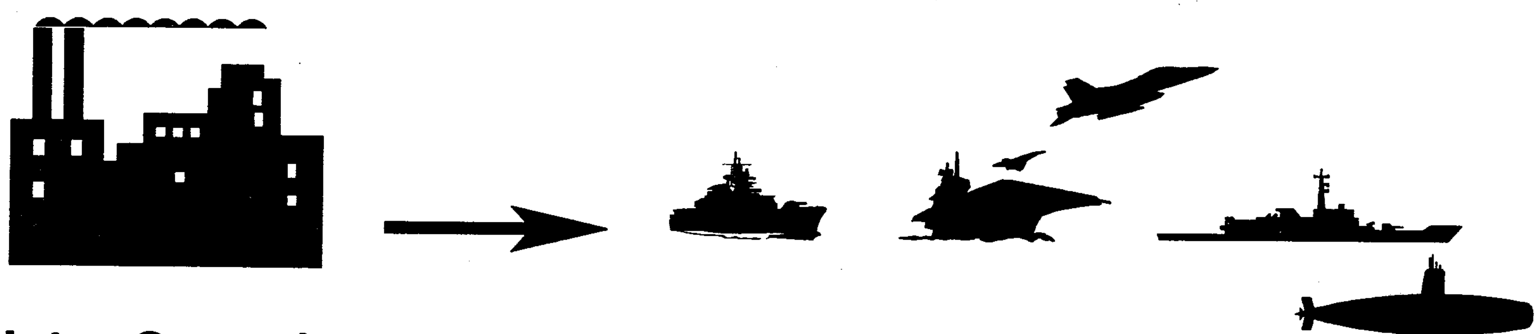


SHARP

Fleet Maintenance Enhancement

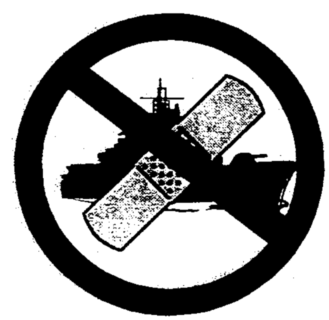
Organizational Process Improvements/Development

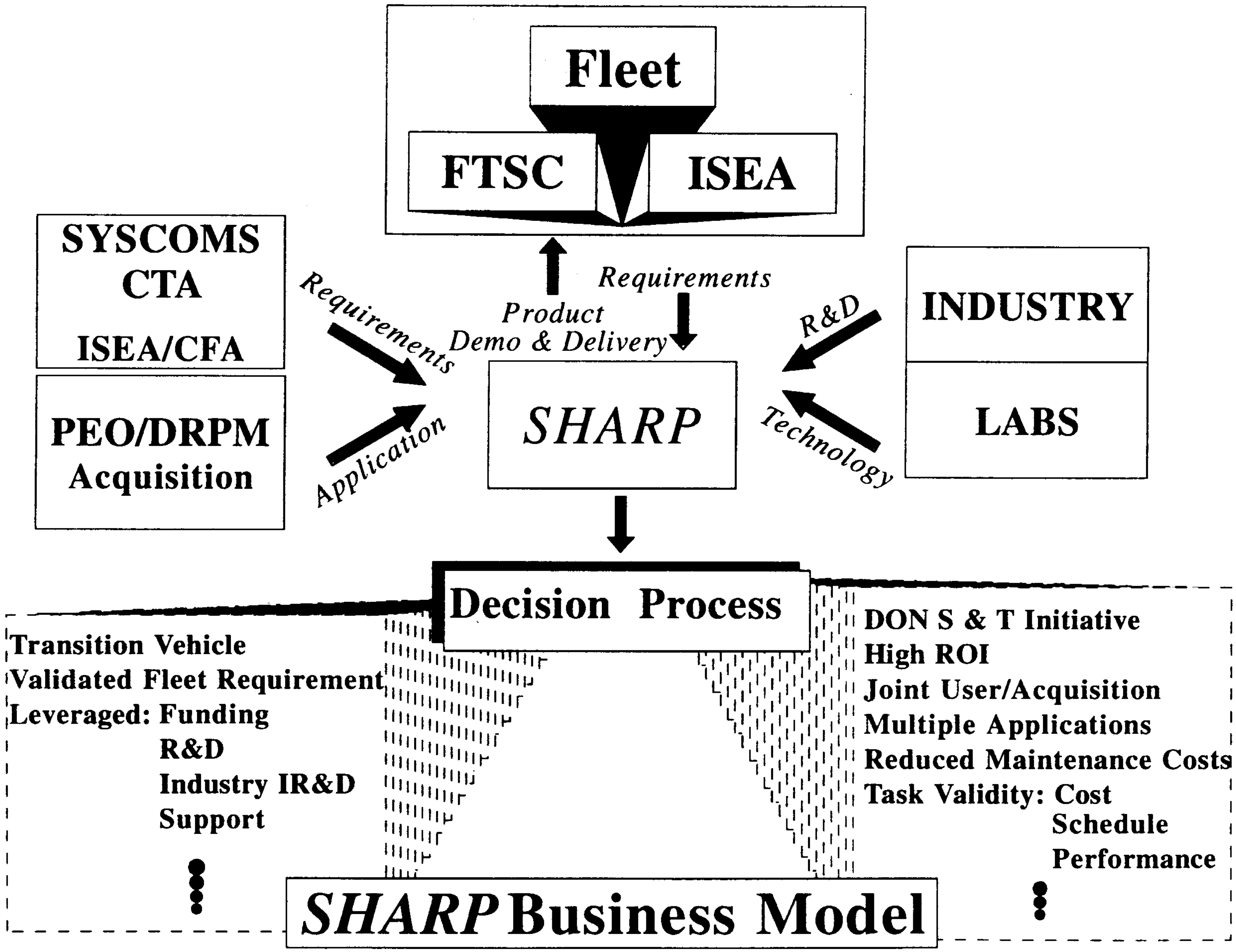
Intermediate Process Improvements/Development



Inter-Operational Maintenance Practices (Factory to Fleet)

Engineering For Reduced Maintenance

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FTSC
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SYSCOMS
CTA
ISEA/CFA
PEO/DRPM
Acquisition
Requirements
Application
Product
Demo & Delivery
Requirements
SHARP
R&D
Technology
INDUSTRY
LABS
Decision Process
Transition Vehicle
Validated Fleet Requirement
Leveraged: Funding
R&D
Industry IR&D
Support
DON S & T Initiative
High ROI
Joint User/Acquisition
Multiple Applications
Reduced Maintenance Costs
Task Validity: Cost
Schedule
Performance
SHARP Business Model

Commercial and Plastic Components

General Description:

Secretary of Defense, Dr. William Perry, has given the DoD the goal of using more commercial products in military systems. This is a reversal for the military, which historically used ceramic hermetically sealed microcircuits. To be able to assist progr ams in this transition, the SHARP program and the Naval Surface Warfare Center, Crane Division, has undertaken several efforts to investigate the use of commercial components in military systems.

Commercial and Plastic Component References:

* "Plastic Packaged Microcircuits: Quality, Reliability, and Cost Issues" is a general article in the IEEE Transactions On Reliability, Vol. 42, No. 4, 1993 December.

* "Reliability Environmental Evaluation of Commercial Plastic ICs for Military Application" - November 1994 Government Microcircuit Applications Conference, (GOMAC) pg. 317-320, by Dan Quearry, Vic Brunamonti

* "Plastic-Encapsulated Microelectronics: Materials, Processes, Quality, Reliability, and Applications" - 1995, textbook by: Micheal G. Pecht, Luu T. Nguyen, Edward B. Hakim, published by John Wiley and Sons, Inc.

*HAST study performed by NSWC-CD on four manufacturers of the same part type: 74F74 Plastic DIP IC (additional information available from Dan Quearry).

Commercial Specs. and Standards

* JESD- 26A is a commercial specification for plastic encapsulated microcircuits for use in rugged applications. The spec. is currently being revised to revision "A" and is to voted on by the EIA counsel in the near future.

* "Stress Test Qualification for Automotive Grade Integrated Circuits" is a specification that defines the minimum stress test driven qualification requirements and references test conditions for qualification of integrated circuits (ICs) for the automoti ve environment. This specification was jointly developed by the Automotive Electronic Council made up of Chrysler, Delco and Ford.

Commercial and Plastic Component Workshop

*Each November the SHARP program and the Naval Surface Warfare Center, Crane Division sponsor a two day "Commercial and Plastic Components" workshop. The first days presentations are from the military or military contractors on the use of commercial components in military applications. The second day is dedicated to industry's use of plastic components in various commercial applications and environments.

* Proceedings for the November 16 & 17, 1994 'Commercial & Plastic Components" workshop held in Indianapolis Indiana can be obtained by contacting Dan Quearry 812 854-2443 or Pam Ingram 812 854-2378.

* The fourth annual "Commercial & Plastic Components" workshop will be held 15 & 16 November, 1995 at the Westin Hotel in Indianapolis Indiana. The point of contact for information and registration is Dan Quearry 812 854-2443 or Pam Ingram 812 854-2378.

Point of Contact For technical assistance on using commercial components in military electronic systems contact:

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ACCELERATING THE USE OF COMMERCIAL INTEGRATED CIRCUITS IN MILITARY SYSTEMS

By

Clifton A. Schwach

November 16, 1995

Good morning

Please allow me to digress for just a minute. I believe it will set the stage for understanding the panel's findings. Let's go from Perry to Perry

In 1933 Admiral Perry prepared to return to the South Pole. To do that successfully he needed reliable communication capability. Perry was the first to demand and get specific long-range reliable radio communication capability. By 1940 the war in Europe was driving a greater need for improved electronics. New radar, bomb sights, radios then the Korean conflict would demand superior equipment to overcome massive human odds. The cession of actual combat in the fifties sparked the cold war which in turn made new demands on technology for surveillance and information gathering. The sixties brought the space race, again new technologies, new demands, and new applications. We could put a man on the moon and bring him back safely. We could walk through fire with new protective suites and enjoy Tang at the breakfast table and many other marvelous things because of the space program.

American and world technology had begun to change. Until then the American tax payer had been the technology driver. By 1980's the consumer had become the technology driver.

Off in the East, Perry was watching. I don't think he is the same Perry who started all of this in 1933; but,

In 1994 Secretary of Defense William Perry recognized publicly what everyone had known privately for a long time. It was time to adjust the government technology paradigm. If we were to continue to maintain our military superiority, we would have to do it with the existing budget and on industry terms.

The Defense Manufacturing Council was chartered to oversee the implementation of an integrated DoD strategy for achieving affordable weapons systems that meet all performance requirements

Under the Defense Manufacturing Council (DMC), the Industry Task Force for Affordablity met in January 1994 and 1995 with a number of industry leaders The product of these meetings is the multi-use manufacturing work panel's findings

The panel's objective was to determine the extent to which commercial integrated circuits could be used in military systems. The panel explored these issues:

1. What is the most effective source for integrated circuit components for DoD? As Mil Spec components? As commercial components? Through a new system? Some mixture of mil and commercial?
2. If the most effective source is different form the current practice, how should a change be accomplished?
3. What are the barriers or uncertainties that limit increasing the use of commercial ICs in military systems?
4. What evidence exists to date that indicates the extent to which commercial ICs can be used in military systems?
5. To what extent (if any) are Standard Microcircuit Drawings and Qualified Manufacturers Lists necessary or desirable for military use of ICs?
6. What impact is there likely to be on the performance, cost, and schedule of systems resulting from use of commercial ICs?
7. To what extent can Plastic Encapsulated Microcircuits be used in military systems, particularly those involving environments with extreme temperature and humidity? What evidence is there for the reliability of Plastic Encapsulated Microcircuits?

The panel held 3 workshops and a symposium each with a broad range of participants from IC manufacturers, military system developers, the military services, and industry trade groups. The symposium was a review of 18 projects where the presenters described how they went about designing commercial components into military applications and, in some cases, how these commercial units actually performed in the field.

The results were overwhelmingly positive. They validated that commercial parts could be successfully incorporated into military equipment. Detailed follow-up interviews were held with designers, quality assurance engineers, and engineering managers in an attempt to determine "How To" design in a mil environment with commercial parts. The fundamental difference between military and commercial designers was determined to be that the commercial designer bears full responsibility for assuring that each component he selects will work properly in the environment of the end product. Conversely, the mil designer feels assured that mil parts will function properly. So the "How To" boils down to a shift in responsibility.

Because data is not readily available for commercial parts in military environment, the panel questioned the value of their original premise: to facilitate use of commercial devices in military equipment to reduce cost. As it turned out, cost was not the primary motivator. Performance was and it was followed closely by "time to market". Cost came in forth after frustration from "red tape" to specify and procure mil parts.

The lessons from the symposium:

1. The use of commercial parts will require the designers to accept responsibility for performance.
2. The component industry will seldom support solutions needed for the unique military application.
3. Qualification of commercial parts for military applications must be specific to application and supplier and rely on the imagination and sound engineering judgment of the designer.

The third workshop targeted the semiconductor industry's support for military applications. The result was a clear understanding that mil designers would most likely be buying their commercial parts from distribution. The QML/SMD system may offer a solution by providing a virtual "military customer" without the burdensome mil spec system thereby avoiding the "no support" commercial system.

The second concern at the workshop was "spares". How can we support systems for 20 years with components whose lifetimes total single digits? This issue of supportability remains the open issue.

Based on the panel's work, they recommend that the order of preference for component selection be reversed from its traditional order and qualification be emphasized.

Step 1 Select commercial components which meet environmental needs.

Step 2 Select QML/SMD components.

Step 3 Select from the QPL/Mil spec component list

Step 4 Any part to be used outside its specified range should be specifically qualified based on economic judgment, engineering skill, and technical risk

This scenario will not be as comfortable or convenient as the environment of the past; but, it will provide the DoD with reasonably priced superior technology in a timely manner

CONCLUSIONS:

The panel drew the following conclusions from the study:

1. The use of commercial integrated circuits in military systems is broadly practical. In many situations ICs in industrial or military temperature ranges are available commercially. In others, standard commercial ICs can be used with appropriate testing or screening.

2. The primary motivation for using commercial ICs in most military design situations is not to reduce cost, but to gain better and more timely access to new technologies While cost is typically a factor, it is usually a minor one

3. The stability of the industrial base for producing specialized military integrated circuits is in serious question. Major suppliers, Motorola and AMD, have recently announced they are leaving the business, and the list is very likely to grow.

4. The use of commercial ICs is unlikely to fulfill all needs of military designers. This is also true of ICs based on military specifications and standards. In particular, military designers are likely to frequently need far more support services from manufacturers than are likely to be available. Some alternate system, such as a system base on Qualified Manufacturer's Lists and Standard Microcircuit Drawings (QML/SMD) is likely needed.

5. Commercial ICs can be used even in space applications where radiation tolerance is needed, particularly in the case of the lower earth orbits

6. The fact that commercial integrated circuits have a far shorter time span for availability than the typical life cycle of a weapons system is a potentially serious problem that is as yet unresolved and needs further study

RECOMMENDATIONS:

1. All military designers should be encouraged to use the new order of preference in which ICs manufactured commercially, by a QML/SMD approach, or by a military specification are considered for use, in that order.

2 A system for the manufacture and procurement of ICs based on QML and SMD should be implemented, at least on an experimental basis, and its value studied for a period of time.

REMAINING ISSUE

The single remaining issue that is still unresolved is the apparent need, or at least expectation, on the part of military weapons systems developers for long-term availability of parts.

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1250 Eye Street, NW, Suite 1100, Washington, D.C. 20005 202 371-8450
NCAT

MULTI ASSOCIATION INDUSTRY AFFORDABILITY TASK FORCE MEMO

TO: Industry Members

11 September, 1995

FROM: Joe Syslo, Task Force Secretariat JMS

SUBJECT: Summary Report, Commercial Integrated Circuits in Military Systems

The enclosed summary report is provided for your review. This report is the final product of Multi-Use Manufacturing Team of the Industry Affordability Task Force. The project, an analysis of the needs of the Department of Defense for access to Integrated Circuit (IC) technology, is an attempt to improve the DoD's ability to have access to the best technology, at lowest cost. Further information on the team's activities or the activities of the Task Force for Affordability can be obtained by contacting the National Center for Advanced Technologies by Facsimile, (202) 371-8470; Voice (202) 371-8455; or Internet, Joe Syslo <ncatt@millkern.com>. Comments on the product would be appreciated.

Attachment

SUMMARY REPORT AND RECOMMENDATIONS FOR ACCELERATING THE USE OF COMMERCIAL INTEGRATED CIRCUITS IN MILITARY SYSTEMS

August, 1995

FINAL DRAFT

Prepared by
The Multi-Use Manufacturing Work Panel
of
The Industry Task Force for Affordability

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Washington, DC 20005
(202) 371-8455
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SUMMARY REPORT AND RECOMMENDATIONS FOR ACCELERATING THE USE OF COMMERCIAL INTEGRATED CIRCUITS IN MILITARY SYSTEMS

INTRODUCTION

This paper reports on a project in which the needs of the Department of Defense for access to Integrated Circuit (IC) technology—in the form of specific IC components— were analyzed, and strategies developed to improve the ability of DoD to have access to the best IC technology for weapons systems in the most timely matter and at the least cost.

The paper is organized as follows:

In the first section, the objectives and approach of the project are presented, including the initial objective and how it evolved over the duration of the project. Additionally, the primary issues to be explored and the general approach we took to attack the problem are detailed.

In the second section, a discussion presents chronologically what we learned as we learned it. We first discuss our initial expectations and our learning experience as workshops were held. A symposium in which examples of actual use of commercial ICs and other relevant information is discussed next. We then present results from followup interviews with designers of example systems, and a summary of general lessons learned from the example systems and follow-up interviews. The issue of design supportability is then confronted, and the resulting need for some system for manufacturing and procurement of ICs that is in addition to the commercial and MIL Spec systems. A methodology for use by military designers to allow them to select parts appropriately from the alternative systems is then described. Finally, the section concludes with a discussion comparing the expectations of participants at the beginning of the project with the actual findings of the project.

In the third section, we present those general conclusions that we drew from the study, including those related to the extent to which commercial ICs, can be used in military systems, the motivation for using them, the stability of the industry base, and other issues.

In the fourth section, we present specific recommendations to DoD concerning what designers of military electronic systems should do to increase their use of commercial ICs, and what DoD should do to provide sufficient alternatives to such designers.

The fifth section discusses the one remaining issue that is still unresolved and that needs further study.

OBJECTIVES, ISSUES, AND APPROACH OF PROJECT

Objectives and Motivation

The initial objective of the task was to determine the extent to which commercial Integrated Circuits could be used in military systems. The primary motivation behind this objective was a desire to reduce cost: it was felt that the military specification system was a very expensive way of doing business, and that substantial economies could be had by taking advantage of the low per-unit costs of commercial chips. Commercial ICs were also seen as a way to obtain better access to

new technologies and reduce the time required for particular chips to be made available for use in weapons systems.

The objective changed somewhat as the project progressed. Soon after the project began, it became clear that commercial ICs could indeed be used to a significant extent, and so the task focused on how to accelerate the use of commercial ICs in military systems. Later in the project, it became clear that lack of support from manufacturers was a critical barrier to using commercial ICs but that other alternatives were available outside of the MIL-spec system. The objective was accordingly broadened to include such issues as the desirability of such alternative systems. It also became apparent that the initial motivation focusing on cost overemphasized the importance of that aspect and underemphasized other motivations, such as performance of ICs and delay in getting products into operational use.

Issues to Be Explored

The following issues were to be explored, and resolved to the extent possible:

1. What is the most effective source for integrated circuit components for DoD? As Mil Spec components? As commercial components? Through a new system? Some mixture of the above?

2. If the most effective source is different from the current practice, how should a change be accomplished?

3. What are the barriers or uncertainties that limit increasing the use of commercial ICs in military systems

4. What evidence exists to date that indicates the extent to which commercial ICs can be used in military systems?

5. To what extent (if any) are Standard Microcircuit Drawings and Qualified Manufacturers Lists necessary or desirable for military use of ICs?

6. What impact is there likely to be on the performance, cost, and schedule of systems resulting from use of commercial ICs?

7. To what extent can plastic encapsulated microcircuits be used in military systems, particularly those involving environments with extreme temperature and humidity? What evidence is there for the reliability of plastic encapsulated microcircuits? Data from simulations? Data from actual system use?

Approach to the Problem

The problem was approached primarily by holding a series of workshops and a symposium at which particular cases were presented. The workshops and symposium had a broad range of participants from integrated circuit manufacturers, military system developers, the military services, industry trade groups (e.g., the Electronics Industry Association), and the Institute for Defense Analyses. Three workshops were held. One workshop, on Commercial IC Capabilities, was held March 29, 1995 at the IDA facilities in Alexandria, Virginia, with 22 participants. A second workshop, on Applications and Operating Environments, was held June 9-10, 1994, with 26 participants, also at IDA. A third workshop, on Design and Supportability, was held December 13-14, 1995, with 15 participants, at IDA. The Case Studies Symposium was held June 13-15, with 43 participants, at IDA.

The workshops and symposium were further supplemented by additional data collection and analysis, and followup studies of some of the cases presented at the Case Studies Symposium, including visits to facilities in Baltimore, Los Angeles, and San Diego.

FINDINGS

Initial Expectations and Experience

From the beginning of this project, the first product expected was an answer to the basic question: "Can we use commercial Integrated Circuits to any significant extent in Military equipment applications?" If the answer was "yes", as most participants expected, then the tasks remaining were to: (1) characterize the various military applications into convenient groupings with similar requirements, (2) select types of commercial ICs that were likely to meet the requirements of each application group, and (3) create for each group of ICs a list of specific part numbers (and suppliers) of commercial components that could be used in designing military equipment of the appropriate type. Thus, the ultimate product of the project was to be a reference manual that military equipment designers could use to select commercial components for their designs, and a database listing parts and their applicability to particular types of systems.

Given such a reference manual and database, all that remained was to remove any bureaucratic barriers that prevent the designer from abandoning the old way of always reaching for a MIL Spec handbook and instead reaching for a commercial parts catalog. In order to promote the new acquisition rules necessary to remove these barriers, it was thought necessary to provide examples (in the form of case histories) of the successful use of commercial parts in military products. It was hoped that these cases would not only show that commercial parts worked satisfactorily but also what the rewards were in terms of cost, rapid availability of components, and technical performance.

The first two workshops (in March and June, 1994) were conducted with these expectations in mind. The participants did some excellent work in categorizing the many diverse military applications and the environments in which they operated. Some preliminary judgments were also made as to which military applications would be most likely to accommodate commercial ICs. Further, data was presented relevant to the performance of commercial ICs operating under military-like conditions.

The third major activity of this project was a case history symposium (in June, 1994). Over 20 companies and government organizations submitted proposals and expressed willingness to present their experiences. Eighteen were chosen for presentation and a two-day symposium was held during which the presenters described, in some detail, how they went about designing commercial components into equipment for military use. In cases where the projects resulted in equipment that had been fielded long enough so that tangible reliability results were available, this data was also shared.

The results of the cases were uniformly positive and encouraged the team members to believe that the use of commercial components in military equipment was a viable concept. It should be recognized that, although the original request for papers did not limit submissions to positive outcomes, we could have predicted that the submissions would be heavily weighted toward the positive side. Few organizations enjoy reporting failures. In fact, all the submissions had positive outcomes. The team did not view the cases as a representative cross section of successes and failures but simply a validation that commercial parts could in fact be successfully incorporated into military equipment.

The case studies seemed to offer another potentially significant insight toward the successful meeting of the project objective. Specifically, the team felt that if they could capture and combine the design methodologies used by the engineers in the case studies, it would be an invaluable addition to project results. In short, it was one thing to tell military designers that they should use commercial components, but substantially more meaningful if those instructions could be coupled with information on *how* to go about the task.

Followup Interviews with Designers of Case Study Systems

In an attempt to further understand the "how to" element of the design process and to better prepare for the third workshop (Design and Supportability), we decided to delve deeper into the rich case study experiences. Members of the team visited 4 of the companies who had presented case studies. Detailed interviews were conducted with design engineers, Quality Assurance (QA) engineers, and engineering managers. From these interviews we synthesized a "best practice" methodology for designing commercial parts into military equipment. Basically this methodology is a simple extension of the process used by all successful designers of commercial equipment. The fundamental difference between the practices of the traditional military designer and the commercial designer seems to be that the latter bears full responsibility for assuring that each component the designer selects will work properly in the environment in which the end product must function. Conversely, the military designer reaches for the MIL Spec handbook and feels assured that all parts meeting a given specification will function properly. The responsibility taken on is not as onerous as it first sounds for the commercial designer: most commercial products will be used in friendly environments and any component, if it exists at all, will work in this benign environment. Automotive and telecommunications equipment designers have environments less friendly than the normal commercial ones, which makes their task more difficult. They too must take full responsibility for the performance of the components they choose.

The military designer trying to use commercial parts does have the problem that many commercial parts won't necessarily work over extended temperature ranges. While a significant number of commercial components are specified over extended ranges, the majority are not. To make matters more frustrating, many commercial parts will actually work over extended temperature ranges (or will work with only slightly degraded performance) but data indicating this is not included in published specifications.

The military designers in our case studies had no magic, or simple, solution to their dilemma. They simply analyzed each component one at a time and somehow qualified it for use in their circuit. The techniques they used included (1) calling friends at the supplier's engineering department and asking for extended temperature test data, (2) calling design engineers on similar projects to see if they used the device under consideration, (3) buying a small quantity of the device and running tests themselves (or in their QA departments). In some cases, the devices would work with equal performance at extended temperatures, in other cases performance was degraded. In the latter situation, our case study designers would determine if the degraded performance could be accommodated in their circuit or if the circuit could be modified to compensate for the degraded performance. In some cases, designers would simply choose a MIL Spec component to avoid the effort of dealing with degraded performance, if such a component was available. For the critical applications, however, MIL Spec components were typically not available.

Considering the amount of extra effort our case study engineers needed to invest in using commercial parts in their military equipment, we began to question the value of our original premise; i.e. to facilitate the use of commercial devices in military equipment. Our case study engineers assured us, however, that it was worth the effort, but not for the reasons we originally anticipated. Our original expectation was that cost reduction was likely to be the most important motivation for switching to commercial parts. Each of the case study engineers we visited had cost on their priority list, but it was never first. Performance was always the prime motivation: either electrical characteristics or size were at the top of the list. These characteristics were simply not available in MIL versions. The second most important characteristic was "time to market": even if the part being considered was expected to become a MIL part, the elapsed time for this to happen was judged to be unacceptable. Other

reasons given for preferring commercial parts were a substantial reduction in the red tape required to specify and procure a part, and cost.

The business environments into which our case study engineers were working seemed to fall into two categories: (1) dual use, i.e. both commercial and military, and (2) military only. Thus the underlying motivations spanned the spectrum between needing to meet competitive commercial pressures to the single objective of providing DoD with a needed technology.

Lessons from the Case Studies and Follow-up Interviews

Three extremely valuable lessons came out of the case studies, and especially the follow up visits, as follows:

(1) The use of commercial parts would require the designer to accept responsibility for the performance of those parts in the environments that the final product must operate. This responsibility would frequently require imagination and sound engineering judgment to address these undocumented circumstances.

(2) There was seldom adequate support provided by the component supplier toward solution of the problems posed by the unique situations in (1) above.

(3) The concept of a catalog or reference manual of commercial parts that can be used in military applications, while appealing on the surface, would be unproductive, if not outright misleading. The design engineers from the case studies felt that their process of qualifying a part for their particular circuit in its particular application yielded extremely unique information. Specifically all that could be said about a particular part, from a particular manufacturer, was that it would work in the intended circuit. Successful application in any other circuit should not be implied. In fact, the same part from a different supplier should be treated as a completely different part in terms of "outside of published spec" performance. One case study company felt so strongly about this conclusion that they would not even assemble a list of commercial parts successfully used in one department for use in another department of the same company.

Supportability and the Need for QML/SMD

At this point we held the third workshop (Supportability and Design Techniques). A more detailed description of the results of the workshop can be found in a separate document.[1] The emphasis of this workshop was changed somewhat from our original intention, because of the lessons learned from the earlier workshops and particularly the lessons from the case studies. This change in emphasis, which we discuss below, dictated a different participant set than we originally anticipated. We invited participation from each of the largest semiconductor houses in the U.S. Accordingly, we fashioned the agenda to elicit from the participants a discussion on two very key issues.

First, we wanted to know what level of support our military designers could expect from suppliers when designing with commercial parts. The processes that the designers had to resort to in our case studies seemed rather inefficient and we felt that a more structured approach might yield a more productive relationship. We were somewhat surprised to learn from our supplier participants that it was extremely unlikely that *any* support would be available from the commercial side of their companies. The volume of business was just too low to attract the attention of the commercial sales force. In fact, most companies participating in the workshop felt that the military designers would have to buy their commercial parts through distributors. This feeling was punctuated by the fact that two of the participants, AMD and Motorola, had recently announced a withdrawal from the military business. Apparently, the size of the military

1. Proceedings of the Supportability and Design Techniques Workshop.

business was not only too small to attract the commercial side of these two companies, it was also too small to support a separate military side of the company.

The industry participants clearly recognized the importance of a sound support base for the military designers and offered an alternate solution to the dilemma. They felt, unanimously, that if the DoD would actively push the QML/SMD system[2] it would provide a backdrop against which they could view the military market as a single entity or a single "virtual" customer. They could, therefore, offer this virtual customer much of the support unavailable to the many military designers acting separately. Obviously the customer would not really be one customer and thus not receive all the support of a single large customer, but nonetheless qualify for substantial support. Although the team was not completely convinced that support under these circumstances would be adequate, we did feel that the QML/SMD system offered an attractive and perhaps necessary middle ground between the expensive, burdensome MIL Spec system and the "no support" commercial system.

Long Term Availability an Unresolved Issue

The second point we wanted to address during the workshop was the issue of the long logistics, or spares, tail that the DoD has traditionally required of their equipment suppliers. Without exception, the case study follow-up visits revealed an absence of concern for providing spares support for their equipment for 20 years. The designers recognized their responsibility for supporting their equipment for a substantial period, but hoped that they would be allowed to employ the traditional commercial approach to spares. Traditionally, commercial manufacturers take full responsibility for the support of their products but not at the component level. They provide ongoing support at the functionality level. In other words, they retain the option to use substitute components or even substitute boards or modules if direct replacements are unavailable. This seems like a satisfactory option to the team, but does leave one important loose end: commercial equipment manufacturers do not support their products for 20 years. They typically provide support for 5 or 10 years, after they cease active manufacturing. The participants of the workshop uniformly concurred that there was no interest by the commercial side of their companies to stretch out component availability to anything near 20 years. In fact, the participants felt that, to the extent that MIL components were tied to commercial devices (such as using the same chip), MIL microcircuits would also have shorter lifetimes of availability. This logistics problem remains an open issue.

Methodology for Use by Military Designers

Based upon the three workshops and the case studies, and heavily influenced by the follow-up visits, we have constructed the following methodology for the selection of ICs by designers of military systems. It is our feeling that this methodology offers the designer the maximum flexibility and opportunity for technical excellence, while recognizing the realities resulting from reduced DoD influence in a very dynamic commercial market.

There are two key elements to our design strategy. The first is that the designer must have readily available a free choice of three different sources of components. These sources are (1) commercial parts, (2) QML/SMD parts, and (3) MIL Spec parts. The second element is that the designer must accept the responsibility for the impact that

2. QML/SMD stands for Qualified Manufacturers List and Standard Microcircuit Drawing, respectively. The QML designation refers to the meeting of process quality standards by the manufacturer. It is significant to recognize that SMD originally stood for Standard Military Drawing and was changed to its present designation a little over a year ago. The intention of this change was to try to bring this standard more into universal use in both the military and commercial world. While it is mostly used in the military world today, the participants felt that it would eventually spread to the commercial world. Both designations are attempts to bring a level of standardization to the microchip industry. There are currently over 8000 parts carrying this designation.

component selections have on the performance of the final product. In discharging this responsibility in the environment described below, the designer will be required to exhibit a considerable amount of initiative, creativity, and adherence to sound engineering principles.

With these elements firmly established, the following process should be followed by the designer: After generating a rough draft of a circuit diagram, or flow diagram, the designer should choose components for the circuit in the following sequence:

1. The circuit designer first selects as many circuit components as possible from commercial catalogs. At this step only components that meet the required operating conditions with the published specifications are selected. Many commercial parts have specifications that provide extended temperature ratings, either in an industrial range (e.g., 0-85 degrees C.) or in the full MIL Spec range (-55 to +125 degrees C.). Thus, depending on how severe the design conditions are, the designer may find the commercial catalogs a useful source for many or even most of the needed components.

2. The circuit designer then seeks components from the QML/SMD catalogs. These components will typically accommodate more severe conditions than the commercial ones and more supplier support will be available. However, the parts will cost more. As many as possible of the remaining components are selected from these lists.

3. As the last step in the first pass of selecting components, the circuit designer chooses parts from the MIL Spec lists. These parts will usually cost substantially more than commercial or QML/SMD parts and require much more effort and time to procure and use. As MIL Specs are cancelled or otherwise reduced in influence, and as manufacturers become less motivated to produce Mil Spec parts, this option will become less frequently used, and this step will probably eventually be eliminated.

4. The circuit designer then revisits the commercial catalogs to search for components that either weren't available from the other sources or are possible substitutes for components from those lists. It must be recognized that the designer is basically on his or her own in qualifying the commercial part for their circuit. Such qualification may range from seeking additional unpublished data from the manufacturer to running performance and/or screening tests by the designer's organization. Whether the effort is worth it depends upon the circumstances. If the component is only available commercially and is a key part of the circuit, it will be necessary to qualify it, almost regardless of the effort needed. If a MIL Spec equivalent to a commercial part is substantially more expensive and the volume relatively large it also might be worth the effort to qualify the commercial part. Here is where economic judgment and engineering skill are required.

5. The last step in this process is to revisit the QML/SMD lists in much the same fashion as was done in the previous step with commercial catalogs. The idea is to see which MIL Spec components chosen in step 3 can sensibly be replaced with QML/SMD parts. Here again, the designer will be considering components that don't quite meet the required operating conditions of their product. However, here there is some support available from the supplier and the job may be somewhat easier, particularly if the incentives are great due to high difference in cost or relatively high volume. The proportion of commercial versus QML/SMD versus MIL Spec parts will depend greatly on the performance requirements and operating environment of the equipment. For many systems in relatively benign environments, all or nearly all commercial parts are likely to be used. For very demanding environments, systems are likely to have a high proportion of QML/SMD parts.

We think the above methodology will provide the DoD with reasonably priced defense electronic products while maintaining the ability to stay at the forefront of technology. This scenario may not be as comfortable or convenient as the design

environments of the past. However, we think it is likely to strike an optimum balance between DoD's needs and the realities of today's world. Clearly, DoD's funds have been dramatically reduced while their assignment to maintain operational superiority remains intact. This is made even more difficult by the commercial explosion of an IC industry who no longer views the DoD as a crucial and necessary customer.

Comparing Expectations with Actual Findings of this Project

At this point it seems appropriate to revisit our original expectations as a check of the completeness and validity of the findings described above. Our first expectation was that we would end up with a catalog, or reference manual, where we would chronicle the commercial devices that have been successfully used in military applications. In that way, future designers could benefit from past efforts to streamline their selection process. As described earlier, we now think that is an impractical idea. When an IC supplier publishes a specification, that specification creates the boundaries around an area of performance inside of which the device is guaranteed to work. When a military equipment designer reports that a device worked satisfactorily in a given product, it only establishes that the device worked at a single point, not throughout an area of performance. All that has been proved is that a single operating condition has been met, in a unique circuit environment with a particular device from a particular manufacturer. There is little assurance that the device will work in other military applications, that would inevitably involve other circuits, environments, and operating conditions. Thus, a specialized parts database for military systems is not desired.

The second expectation that we had was that we would ultimately propose a series of experiments and demonstrations. After reviewing the case studies and making the follow-up visits, we concluded we had captured the essence of what we needed to learn. We don't pretend that we know all there is to know about this subject, but we do feel that additional experiments and demonstrations are of marginal utility at this time. If the above methodology is adopted by the DoD, it would be worth while to revisit the issue of demonstrations and experiments at a later date to test the efficacy of the methodology.

Another expectation we had for the project was that we would address both legacy and new systems. Our attention, as evidenced by the discussion above, focuses on new systems, apparently to the exclusion of legacy systems. This was primarily driven by our available experiences, the case studies, which dealt solely with new systems. We were probably also influenced by conventional industrial wisdom which tends to leave legacy systems alone once they are invented, particularly on low volume products. It is seldom worth the effort to qualify new components in existing products unless the old components didn't work properly. However, in retrospect, we do feel that the methodology described above is just as applicable to legacy systems as it is to new systems. Should DoD wish to pursue the application of this methodology on legacy systems, we advise beginning the process with Step 4 above. The initial selection of the components (Steps 1 - 3) has already been done and a MIL Spec part has been chosen. What remains is to see if a commercial component exists that could probably do the job and to decide if the effort to qualify the commercial part is worth the cost savings. If Step 4 does not produce an attractive alternative, Step 5 should be undertaken using the same process but with a QML/SMD component.

In this report, we have not tried to present definitive answers that resolve all of the issues presented earlier in this paper. As the project progressed, it became increasingly clear that not only was the data not easily available to allow such answers, but the situation was very volatile and undergoing considerable change. The Perry memo and similar activities initiated significant changes in procurement policies and practices. In addition, reduced demand for military components has already resulted in changes in the industry, such as the withdrawal of Motorola and

AMD from the military electronics business, and is likely to cause additional change. This volatility suggests that analysis of current data would do little to resolve the issues above.

We have, rather, presented in the report a general analysis of the problems and what needs to be done about them. We also applied a specific methodology for use by military designers that depends on the availability of components from three systems: commercial ICs, what might be termed "semi-commercial" ICs manufactured and procured according to the QML/SMD process, and MIL Spec components, with the expectation that MIL Spec components will be used less and less and the MIL Spec system will probably eventually be eliminated.

CONCLUSIONS

We drew the following conclusions from the study:

1. **The use of commercial integrated circuits in military systems is broadly practical.** In many situations ICs in industrial or military temperature ranges are available commercially; in others standard commercial ICs can be used with appropriate testing or screening.

2. **The primary motivation for using commercial ICs in most military design situations is not to reduce cost, but to gain better and more timely access to new technologies.** While cost is typically a factor, it is usually a minor one.

3. **The stability of the industrial base for producing specialized military integrated circuits is in serious question.** Two major suppliers, Motorola and AMD, have recently announced they are leaving the business, and others are also likely to do so.

4. **The use of commercial ICs is unlikely to fulfill all needs of military designers, nor is the use of ICs based on military specifications and standards.** In particular, military designers are likely to frequently need far more support services from manufacturers than are likely to be available if commercial components are used. Some alternate system, such as a system based on Qualified Manufacturer's Lists and Standard Microcircuit Drawings (QML/SMD) is likely needed.

5. **Commercial ICs can be used even in space applications where radiation tolerance is needed, particularly in the case of the lower earth orbits.** Care must be taken, however, to select parts with appropriate resistance to radiation.

6. **The fact that commercial integrated circuits have a far shorter time span for availability than the typical life cycle of a weapons system is a potentially serious problem that is as yet unresolved and needs further study.**

RECOMMENDATIONS

1. **All military designers should be encouraged to use the methodology described earlier, in which ICs manufactured commercially, by a QML/SMD approach, or by a military specifications process are considered for use, in that order.**

2. **A system for the manufacture and procurement of ICs based on QML and SMD should be implemented, at least on an experimental basis, and its value studied after a period of time.**

REMAINING ISSUE

The single remaining issue that is still unresolved is the apparent need, or at least expectation, on the part of military weapons systems developers for long-term availability of parts.

Texas Instruments
Military Products

USE OF COMMERCIAL ICs IN MILITARY SYSTEMS

BSG 11/95

Texas Instruments

Perry Directive

"...We're going to rely on performance standards ...instead of relying on milspecs to tell our contractors how to build something... There will still, of course, be situations where we will need to spell out how we want things built in detail. In those cases, we still will not rely on milspecs but rather on industrial specifications [i.e., non-government standards]...In those situations where there are no acceptable industrial specifications, or for some reason they are not effective, then the use of milspecs will be authorized as a last resort, but it will require a special waiver."

Secretary of Defense William J. Perry
June 29, 1994 Press Conference

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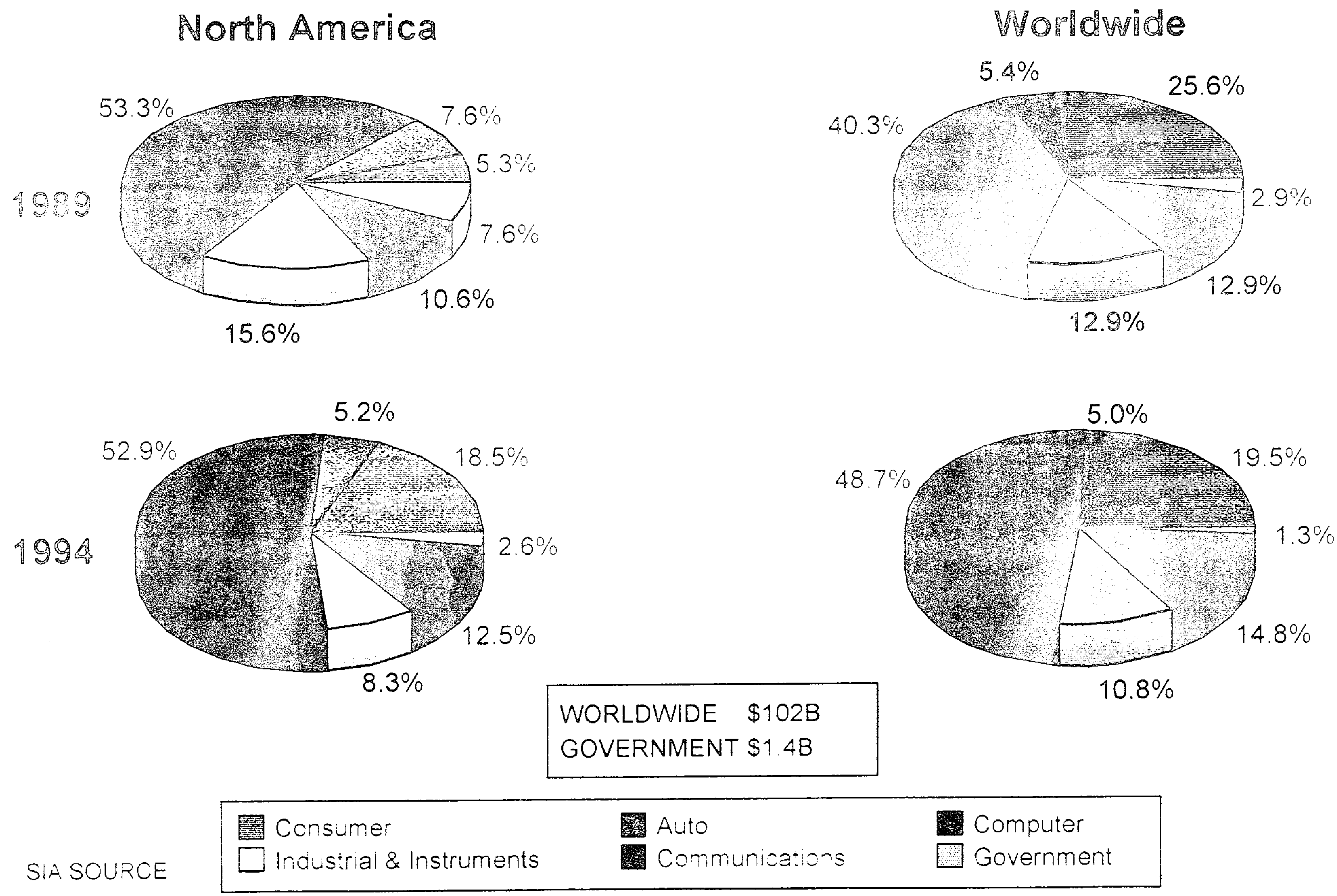
Total Semiconductor End Use
North America & Worldwide



SIA SOURCE

OTHER U.S. MARKETS IN THE SAME RANGE AS MILITARY (1993)

ELECTRONICS ($ B)		GENERAL ($ B)	
CELLULAR PHONES	- 1.3	MUSICAL INSTRUMENT	- 1.3
MODEMS	- 1.6	MOTORCYCLES & PARTS	- 1.8
HOME SECURITY SYSTEMS	- 1.1	GOLF EQUIPMENT	- 1.7
PATIENT MONITORING SYSTEMS	- 1.1	GYM & EXERCISE EQUIPMENT	- 2.0
TELEPHONES (CORDLESS)	- 1.1	HANDBAGS & PURSES	- 1.3
TELEPHONES (CORDED)	- .6	CHEWING GUM	- 1.1
		DENTAL EQUIPMENT & SUPPLIES	- 1.4

SOURCE SIA

SOURCE U.S. INDUSTRIAL OUTLOOK

RECENT SPECIFICATION CHANGES

QML APPROVED AS A PERFORMANCE SPECIFICATION

SUBJECT: Approval of Performance Specification Conversion for MIL-I-38535

TO: DESC-EL

1. Reference DESC-ELDM letter of 7 Feb 95 regarding this subject, DSIC Policy Memorandum 95-2 "Processing Performance Specification", and the DLA Performance Specification Certification Procedures dated 10 March 95.

2. After reviewing the subject document and the justification provided in the referenced letter, we concur that is a performance specification and approve its conversion.

3. Please convert this document to a performance specification in accordance with the procedures in DSIC Policy Memorandum 95-2. A Service Detachment Office should be sent to the OADS(ES)/IA/AP with a copy of the applicable specification and the new cover sheet.

4. This specification must be prepared in accordance with the requirements of MIL-STD-961D (pending) and the document identifier should be changed to MIL-PRF-38535 in accordance with the pending revision of Policy Document 95-2.

5. Thank you for your continued support of this essential program. The point of contact for this action is Mr. David Taylor, DSN 284-6775, commercial (703)274-6775, Fax (DSN) 284 or (703)274-7830.

Dave A. Taylor
DLA Department
Standardization Office

RECENT SPECIFICATION CHANGES

OFFSHORE WAFER FAB APPROVAL FOR QA

SUBJECT: Allowing Use of Offshore Wafer Fabrication Facilities for Monolithic devices.

The onshore restriction specified in Department of Defense (DoD) 4120.3-m, "Defense Standardization Program Policies and Procedures," is waived for monolithic devices covered by MIL-PRF-38535. Please proceed with covering the Offshore wafer fabrication facilities under the MIL-PRF-38535 Qualified Manufacturing List.

Walter B. Bergman
Director
Acquisition Practice

Texas Instruments

MIL-PRF-38535 QML PROGRAM STATUS

COMPANY

ANALOG DEVICES
AT&T
AMI
CYPRESS
HARRIS
HONEYWELL
INTEL
LORAL
LINEAR TECHNOLOGY
LINFINITY
NATIONAL
PHILIPS
SILICONIX
TEXAS INSTRUMENTS
UNITRODE
UTMC
MICRON *
MOTOROLA *

MORE THAN 7800 DEVICES LISTED

*WAFER ONLY THROUGH CHIP SUPPLIER

COMPARISON OF COMMERCIAL/ BEST COMMERCIAL PRACTICES AND QML

- ➡ MOST OF TEXAS INSTRUMENTS STRATEGIC CUSTOMERS (AUTOMOTIVE, COMPUTER, TELECOM) HAVE THEIR OWN SPECIFICATIONS THEY IMPOSE ON TI. THESE SPECIFICATIONS DEFINE THE PROCESS AND TEST PROCEDURES.

- ➡ BECAUSE OF THE VERY HIGH VOLUME EACH OF THESE CUSTOMERS HAS, TI WILL ACCEPT AND SUPPORT THESE SPECIFICATION REQUIREMENTS. THESE SPECIFICATIONS DEFINE BEST COMMERCIAL PRACTICES.

- ➡ THE QML, WHICH HAS THE SAME REQUIREMENTS, ALLOWS FOR THE MANY, RELATIVELY SMALLER IN VOLUME, MILITARY CUSTOMERS TO MEET BEST COMMERCIAL PRACTICES.

- ➡ THE SMALL VOLUME COMMERCIAL ACCOUNT CANNOT DO THIS.

AUTOMOTIVE ELECTRONICS COUNCIL
QUALITY REQUIREMENTS FOR SEMICONDUCTORS

General Requirements

Quality Systems Requirements - ISO 9001

- Management Responsibility
- Quality System
- Specification Review
- Design Control
- Document and Data Control
- Sub-Contractor Control
- Control of Customer Supplied Product
- Production Identification and Traceability
- Process Control
- Inspection and Testing
- Inspection, Measuring and Test Equipment
- Inspection and Test Status
- Control of Non-Conforming Material
- Corrective and Preventive Action
- Handling, Storage, Packaging and Delivery
- Control of Quality Records
- Internal Quality Audits
- Training
- (Servicing intentionally omitted)
- Statistical Techniques

Requirements in addition to ISO 9001:

* Self assessment according to CDF-AEC-A100
* Evaluation scoring criteria
* FMEA
* Cross functional teams
* Appearance item inspection
* Lab accreditation
* Production Part Approval Process (PPAP)
* Manufacturing Capabilities (Assessment)

Industry Common Requirements

ISO 9001

MIL-STD-883 - Test Methods and Procedures for Microelectronics

JEDEC JESD-22 - Reliability Test Methods for Packaged Devices

UL-STD-994 - Test for Flammability of Plastic material for parts in Devices and Appliances

ASTM F-10, Method F459; Wire Pull Test

EOS/ESD Association Specification S5.1-1993

EOS/ESD Association Specification S5.1-(to be released)

JEDEC Standard No. 17 August 1988 (reference IC Latch-up Test)

Special Requirements

CDF-AEC-Q100 Stress Test Qualification for Automotive-Grade Integrated Circuits

CDF-AEC-Q100-001
Bond Shear Test

CDF-AEC-Q100-002
Human Body Electrostatic Discharge Test

CDF-AEC-Q100-003
Machine Model Electrostatic Discharge

CDFG-AEC-Q100-004
IC Latch-up

CDF-AEC-Q100-005
E^2PROM Endurance Test

CDF-AEC-Q100-0065
E^2PROM Data Retention Test

CDF-AEC-Q100-007
Electro-Thermally Induced Gate Leakage Test

CDF-AEC-Q101
Stress Test Qualification for Automotive Grade Discrete Semiconductors

JA100 (Series of test methods)

TI SC AUTOMOTIVE DEVICES
(FORD, CHRYSLER, DELCO)

TI AUTOMOTIVE PARENT DEVICES

101957LP	LM2930-8LP	SN103488N	SN75176BD	TL751M10CKC	TMS70C20
27C128D	LM324N	SN103556NG	SN75176BP	TL780-05CKC	TMS70C40
27C256D	LM358P	SN103562NE	SN75435NE	TL780-05QKC	TMS70C40A
27C512D	LM393D	SN103598P	SN75512CN	TLC1550IFN	TMS70C42A
2C256-2J	LM393P	SN103694D	SN75518FN	TLC274N	TPIC0299KV
5400	L27C128	SN103776N	SN77311P	TLC2772CD	TPIC2801KV
5440	L27C256D	SN104013N	SN94233CNG	TLC27M4IN	TPX371E1600
5453	L27C256GU	SN104038DW	STANDARD CELL	TLC372CP	UA78L10ACLP
74ALS74A	L27C480	SN104087D	TL072CP	TLC533AIN	UA78M05CKC
74HC157	L27C512D	SN104087P	**TL074CN**	TLC5451FN	ULN2004AN
74HC165	L27C512GUA	SN104093N	TL2829ZN	TLC5451DW	
74HC594	L28F010	SN104093NT	TL298KV	TLC555CP	
ADC0831AIP	L28F210	SN104193NE	TL431CLP	TMC9801	
ADC0832AIP	L28F400	SN104194Y	TL4810BIN	TMP320C51	
ADU542F	NE5534P	SN104195KC	TL494CN	TMS1000	
ADU545E	SE371E16092	SN104407Y	TL5812FN	TMS1000CS	
B104038IN	SN100227N	SN65518FN	TL5812IN	TMS320C53	
C-65LB0431Y	SN102954HS	SN65518N	TL5812N	TMS3734	
GEC16	SN103414KV	SN75076B	TL750L05QKC	TMS3734FN	
LM1864BP	SN103471D	SN75116N	TL751F10QKC	TMS7440	

QML: A Process to Achieve a Performance Based Specification

	Product Name	Performance Specification	Process Specification
Before QML	QPL 38510 SMD 883	Slash Sheet SMD Data Book	883 883 883
	Unchanged	Unchanged	Non-value added flows can be eliminated when supported by data (example 100x, centrifuge, temp cycle, and burn-in)
After QML	QPL 38510 SMD 883	Slash Sheet SMD Data Book	**QML**

Old Process Specification - 883C with how to do specified in methods 5004 and 5005

New Performance Based Specification - QML with how-to not specified. JAN slash sheet/SMD or TI data sheet electrical performance requirements.

DESC audits each QML supplier to insure quality system including SPC are in place allowing that supplier to eliminate NVA flows.

"Screening doesn't make parts better, parts survive screens--they don't become better parts"--Jim Blanton, DESC

Qualified Manufacturer Listing
Excerpts from MIL-PRF-38535

- Paragraph 1.1

  "The intent of this specification is to allow the device manufacturer the flexibility to implement best commercial practices to the maximum extent possible"

  "... If sufficient quality and reliability data is available, the manufacturer, through the QM program and the TRB, may modify, substitute, or delete tests."

Texas Instruments

FLOW COMPARISON

QPL

DIE PREP
DIE MOUNT
BOND
40X INSPECT
100X INSPECT
SEAL
TEMP CYCLE
CENTRIFUGE
SOLDER DIP
BURN-IN
25 DC/AC
25 DC/AC L/A
125 DC/AC
125 DC/AC L/A
SOLDER DIP
-55 DC/AC
-55 DC/AC L/A
GL/FL
EXTERNAL VISUAL

QML

(BEST COMMERCIAL PRACTICE)

DIE PREP
DIE MOUNT
BOND
40X INSPECT

100X INSPECT
PROCESS MONITOR

SEAL

TEMP CYCLE/CENTRIFUGE
PROCESS MONITOR

SOLDER DIP

BURN-IN
PROCESS MONITOR

25 DC/AC
125 DC/AC
-55 DC/AC

-55 HC
PROCESS MONITOR

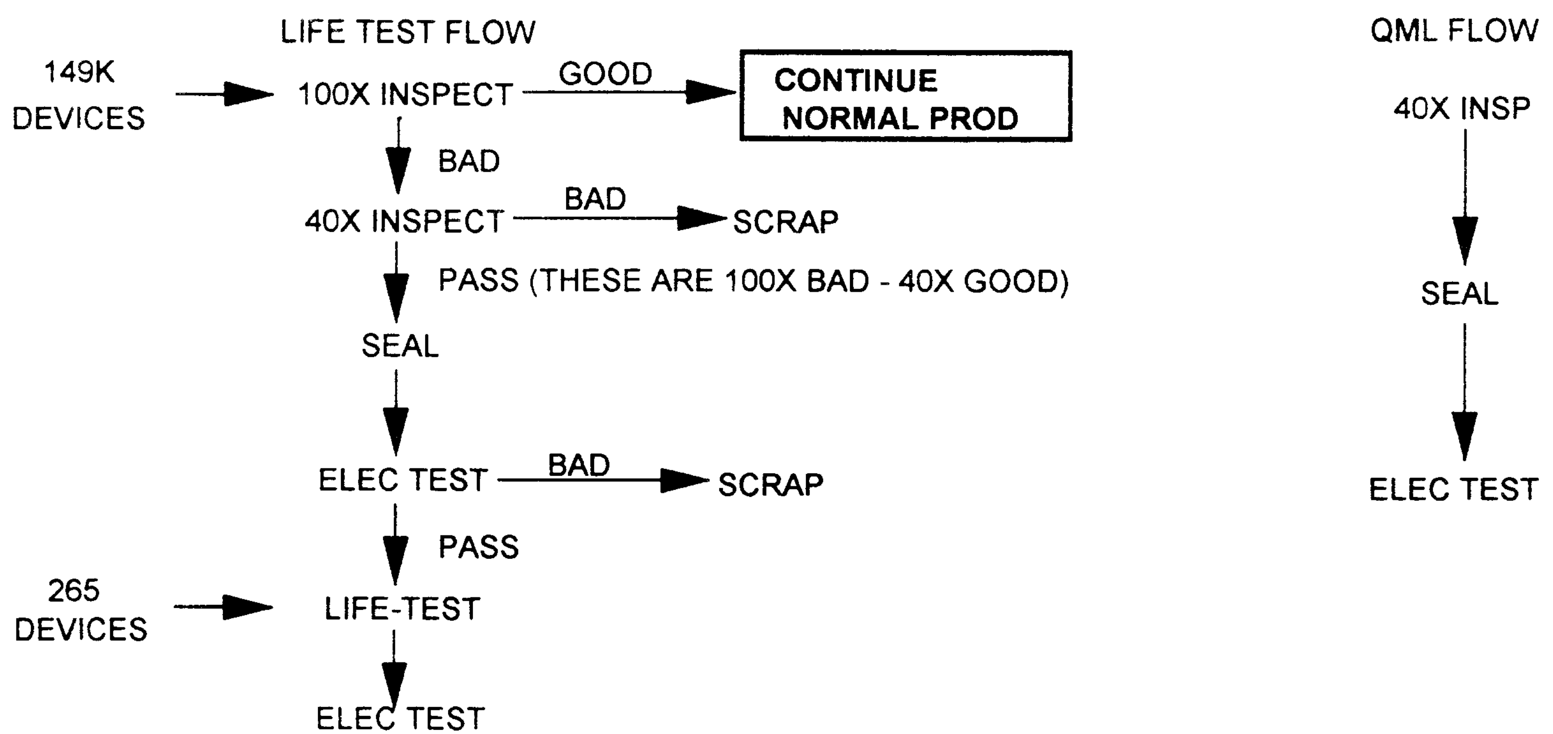
QRP A
-55,25,125 C
PROCESS MONITOR

GL/FL
EXTERNAL VISUAL

Texas Instruments

100X PRE-CAP

- APPROACH WAS TO DETERMINE THE EFFECTIVENESS OF 100X PRE-CAP INSPECTION TO REMOVE POSSIBLE LATENT FAILURES. ON DEVICES WITH GEOMETRIES LARGER THAN 3 MICRONS AND TO DETERMINE THE EFFECT OF THESE DEVICES ON THE FIT RATE OF THE DISTRIBUTION OF THE SAMPLE.
  - 100X HAS BEEN ALLOWED TO BE DELETED ON GEOMETRIES SMALLER THAN 3 MICRONS
  - COMMERCIAL LIFE TEST DATA SHOWS NO PROBLEMS WITH THESE DEVICES
- APPROXIMATELY 149K DEVICES WERE BUILT USING THE QML FLOW SHOWN BELOW. AFTER 40 X AND ELECTRICAL TEST, 265 REJECTS RESULTED AND THESE DEVICES WERE PLACED ON LIFE TEST.



- 265 UNITS HAVE COMPLETED LIFE TEST. LOGIC DEVICES HAD ZERO FAILURES. 5 LINEAR DEVICES FAILED. ALL FAILURES WERE EOS.

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BURN-IN ELIMINATION STATUS

- INITIAL SAMPLE SIZES OF APPROXIMATELY 15K DEVICES BY TECHNOLOGY WERE CHOSEN TO DETERMINE IF BURN-IN ELIMINATION WAS POSSIBLE. THIS IS ROUGHLY EQUIVALENT TO TO ONE FIT FOR TTL, S, AND LS (.96 EV, 168 HOURS AT 125 DEGREES C, 60% CONFIDENCE LEVEL) WITH ZERO FAILURES.

THESE SAMPLE SIZES HAVE NOW BEEN EXPANDED AS SHOWN BELOW:

	SS	FAIL	FITS	
TTL	54858	5	1.7	CURRENT LS CERAMIC FIT RATE IS APPROXIMATELY 2
S	63347	13	3.5	
LS	76865	7	1.6	
TOTAL	195070	25	2.1	

20 FAILURES ARE EOS/ESD. ELIMINATING EOS/ESD FAILURES GIVES 0.5 FIT RATE.

1 FAILURE DUE TO DIE MECH. DAMAGE
1 BOND BOUNCE
1 FAILURE NOT RESOLVED
2 FA PENDING

- ACTIVATION ENERGY FOR HCMOS IS .7 EV. CURRENT RESULTS ARE SHOWN BELOW:

	SS	FAIL	FITS
HCMOS	100165	9	8.0

8/9 FAILURES ARE EOS/ESD. ELIMINATING EOS/ESD FAILURES GIVES 1.6 FIT RATE.
1 BROKEN PACKAGE PIN (DISCOUNTED)

Texas Instruments

HC & HCT
-55 DEGREE ELECTRICAL TEST ELIMINATION

* APPROACH WAS TO DETERMINE THE IMPACT OF -55C TESTING ON OUTGOING QUALITY OF DEVICES.

* TEST FLOW IS BASED ON ELECTRICALLY GOOD UNITS. PARTS SHOULD NOT FAIL UNDER NORMAL TESTING AT -55 IF THEY HAVE PASSED 125C TESTING.

* TO DATE WE HAVE TESTED 226,702 DEVICES AND 18 HAVE FAILED.
  - 13 FAILURES WERE CONFIRMED GOOD.
  - 4 FAILURES DUE TO HANDLING DAMAGE.
  - 1 FAILURE TEST ESCAPE (DAMAGED BOND WIRE)

FLOW

125C DC/AC
↓
125C GROUP A
↓
-55C DC/AC
↓
-55C GROUP A
↓
25C DC/AC
↓
25C GROUP A

COMPARISON OF PACKAGE/FLOW OPTION

	COMMERCIAL PLASTIC	QML PLASTIC	QML CERAMIC
INITIAL PRICE	LOWEST	MID RANGE	HIGHEST
PRODUCT SOURCE	DISTRIBUTION	DIRECT OR DISTRIBUTION	DIRECT OR DISTRIBUTION
TEMPERATURE RANGE	TYPICAL 0-70	-55 TO 125	-55 TO 125
TEST PROGRAM	COMMERCIAL DATA SHEET	SMD	SMD
LEAD FINISH	PD	PD	HOT SOL DIP
LONG TERM RELIABILITY	GOOD	GOOD	BEST
SUPPLIER RESPONSIVENESS	DEPENDENT ON REVENUE	HIGH	HIGH
STORAGE/ PROCESSING	SOME ADDITIONAL REQUIREMENTS	SOME ADDITIONAL REQUIREMENTS	AS CURRENT

TOTAL COST OF OWNERSHIP DEPENDS ON PROGRAM REQUIREMENTS

Texas Instruments

COMPARISON OF PACKAGE/FLOW OPTION

	COMMERCIAL PLASTIC	QML PLASTIC	QML CERAMIC
AVAILABILITY	POSSIBLE ALLOCATION	GOOD	GOOD
PRODUCT PORTFOLIO (SPECTRUM)	BEST	WEAK-GOOD	GOOD
TIME TO MARKET	BEST	GOOD	GOOD
OBSOLESCENCE CONTROL	MINIMAL	BETTER	BEST
TRACEABILITY	MINIMAL → GOOD	BEST	BEST
OTHER CONTRACTORS REQUIREMENTS	NOT AVAILABLE	AS REQUIRED	AS REQUIRED
SUPPLIER CERTIFICATION	BY USER	DESC	DESC
SUPPLIER SELECTION	CRITICAL	LESS IMPORTANT	LESS IMPORTANT

TOTAL COST OF OWNERSHIP DEPENDS ON PROGRAM REQUIREMENTS

Comparison Between Military and Commercial Temperature Test Limits

Commercial and industrial devices are designed and maintained to operate over a more narrow temperature range (typically either 0-70 or -40 to 85 degrees Celsius) than military devices (-55 to 125 degrees Celsius).

As a result of this, the military test engineer must evaluate each device as the device is first released, redesigned, shrunk or has a major wafer fab process change. In some instances issues are found. In all cases the device will meet either the existing or revised commercial or industrial device specification prior to release.

These issues are resolved by the military test engineer in many ways including die banking the older die, adjusting the wafer fab process, continuing to use the older die for military only, changing the military device specification, redesigning the die and deleting the device from the military device list offered to the customer.

Some recent examples are show below:

LM139	(Vol @ 125) Minor circuit redesign.
LM124	(Voh @ -55) Complete die redesign.
SNJ55122	(Vol @ 125) Changed data sheet.
SNJ54LS174	(Iil @ -55) Changed wafer fab process.
LM111	Using different die.
SMJ34082A	Fail functional patterns at -55. Temperature was relaxed.
SMJ416400	Pause time reduced from 64 ms to 34 ms at 125.

In all the cases listed above the military user could have encountered system issues if the commercial device were purchased and used.

RECENT ADDITIONAL DEVICES ISSUES

(ALL MEET THE COMMERCIAL REQUIREMENTS!)

DEVICE	ISSUE	
SMJ320C80	WILL NOT MEET THE COMMERCIAL FREQUENCY OVER THE MILITARY TEMPERATURE RANGE	
SMJ684000	DATA RETENTION IS NOT A COMMERCIAL REQUIREMENT	
SMJ44251	VIH CHANGED FROM 2.4 V @ 0-70 TO 2.9 V OVER MILITARY TEMPERATURE RANGE	
SNJ54LS00	ICCL @ -55 C	
SNJ5404	VOH @ -55 C	
SNJ5474	VOL @ -55 C	
SNJ54S163	FUNCTIONAL @ 125 C	
SNJ54S32	VOH @ -55 C	ALL RUNNING DIFFERENT DIE OR WAFER-FAB PROCESSES THAN COMMERCIAL
SNJ54AS04	VOL @ -55 C	
SNJ54ALS244	TP @ -55 C	
SNJ54F04	IOD @ -55 C (MILITARY ONLY REQUIREMENT)	
LM118	AV @ 125 C	
MC1558	VOM @ -55 C RELAXED DATA SHEET	

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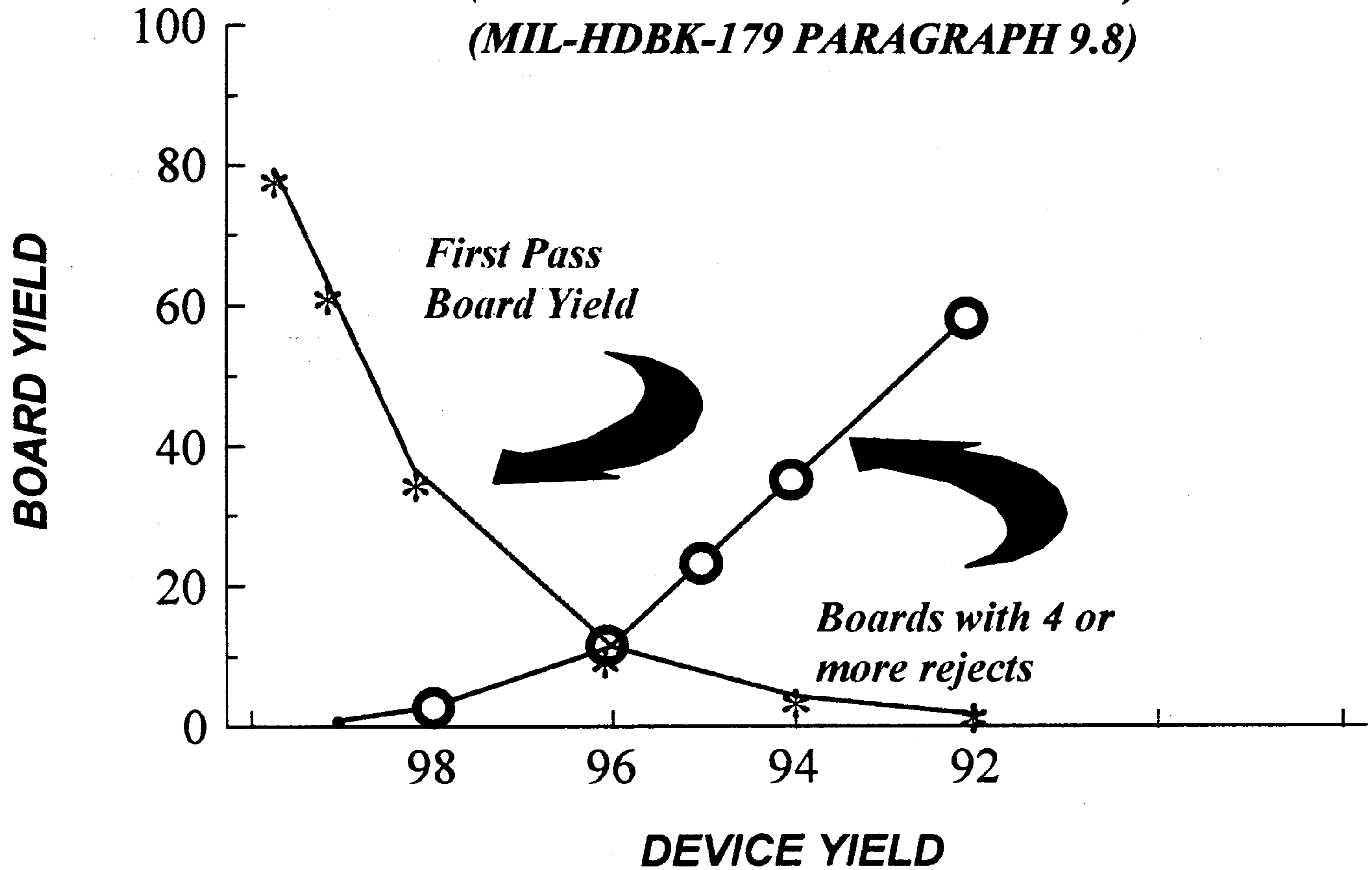
BOARD YIELD VS I.C. YIELD

(BASED ON 50 I.C.'S PER BOARD)

(MIL-HDBK-179 PARAGRAPH 9.8)



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CARE AND HANDLING OF PLASTIC PACKAGES

- DIPS CAN BE HANDLED RELATIVELY SIMPLY SINCE WAVE SOLDER OPERATIONS DO NOT CAUSE BODY TEMPERATURE TO RISE MUCH ABOVE 130 DEGREES C
- SURFACE MOUNT PACKAGES WILL ACHIEVE THE REFLOW TEMPERATURE VERY RAPIDLY, CAUSING ANY TRAPPED MOISTURE IN THE PACKAGE TO CONVERT TO STEAM CAUSING POSSIBLE PACKAGE DELAMINATIONS ON SOME PACKAGES
  - TEXAS INSTRUMENTS ENSURES THAT MINIMAL AMOUNTS OF MOISTURE REMAIN IN THE PACKAGE BY BAKING THE PRODUCT AND OR STORING IN LOW HUMIDITY TEMPERATURE CONDITIONS FOR SHORT PERIODS OF TIME BEFORE DRY PACKING
  - DEVICES ARE PACKAGED WITH DESICCANT AND HUMIDITY INDICATOR
  - IF CUSTOMER OPENS DRY PACK BAG, HE MUST RESEAL BY BAKING AND OR STORING IN LOW TEMPERATURE AND HUMIDITY CONDITIONS FOR SHORT PERIODS OF TIME BEFORE RESEALING

Texas Instruments

MOISTURE SENSITIVITY LEVELS FOR PLASTIC SURFACE MOUNT PRODUCT

LEVEL	FLOOR LIFE	PACKAGE
1	UNLIMITED	ALL DIPS
2	1 YEAR	-
3	168 HOURS	68, 84 PLCC 80, 100, 144, 160 PQFP
4	72 HOURS	64 PM, 100 PZ
5	24 OR 48 HOURS	-
6	6 HOURS	-

PER JEDEC STD A-112

PEM PERFORMANCE DATA

NOT ALL PLASTIC IS CREATED EQUAL!!

TI DATA (LOGIC DEVICES FROM 6 DIFFERENT SUPPLIERS)

LIFETEST
0.1 TO 66 FITS

AUTOCLAVE
.01 TO 4 % FAIL

TEMP CYCLE
.04 TO 27 % FAIL

BIASED HUMIDITY
.01 TO 2 % FAIL

UNIVERSITY OF MARYLAND DATA - LIFE TEST (SEVERAL SUPPLIERS)

LINEAR I.C.	.6 TO 460 FITs	MICROPROCESSOR	3.8 TO 190 FITs
DIGITAL I.C.	5.0 TO 7.1 FITs	MEMORIES	2.5 TO 50 FITs

NSWC DATA (LOGIC DEVICES FROM 4 SUPPLIERS)

	HAST DIP	HAST SOIC
50% FAILURE	300 TO 1300 HRS 50% FAIL	200 TO 400 HRS

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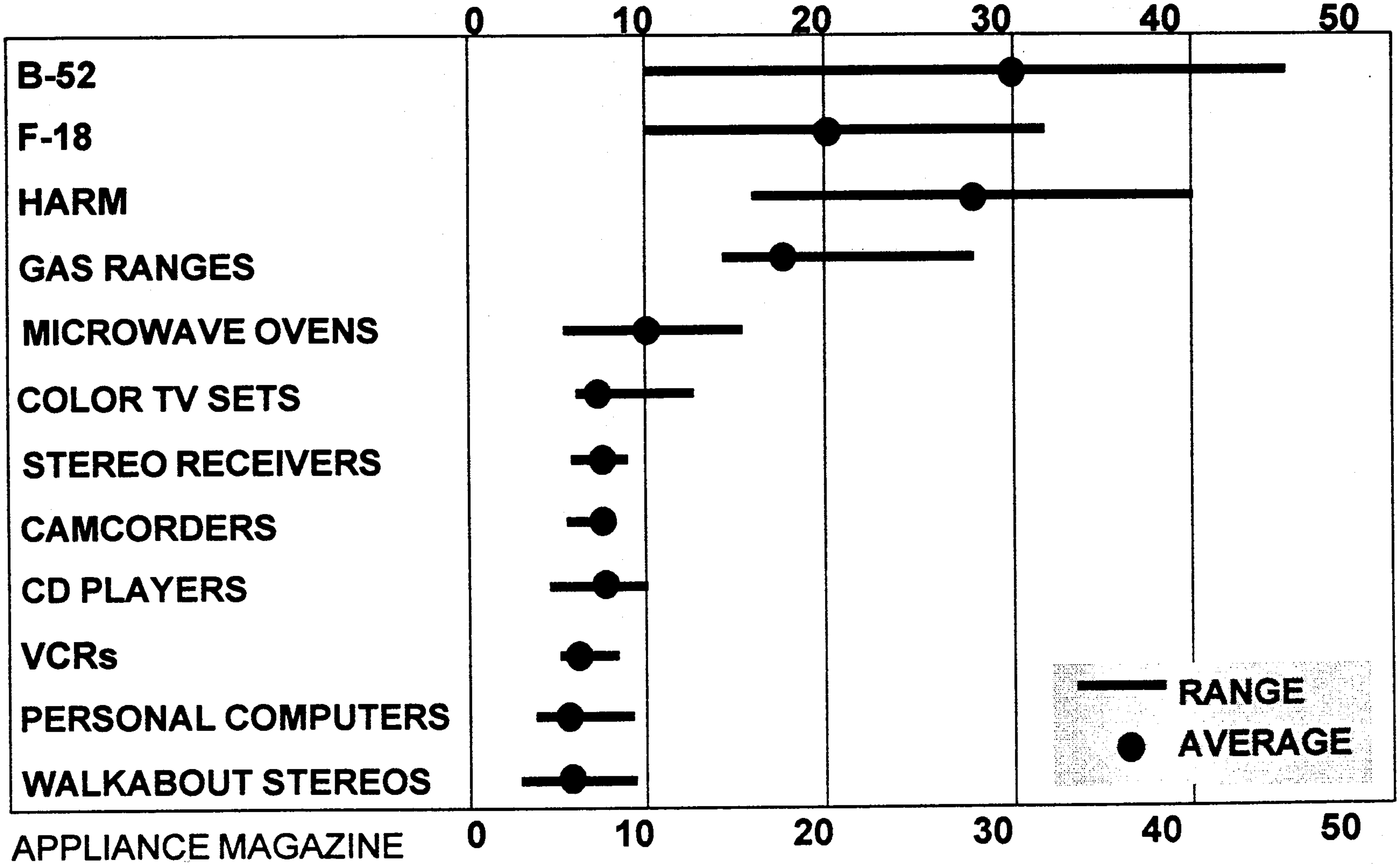
HOW LONG THINGS LAST
AGE AT WHICH PRODUCTS ARE REPLACED (YEARS)



APPLIANCE MAGAZINE

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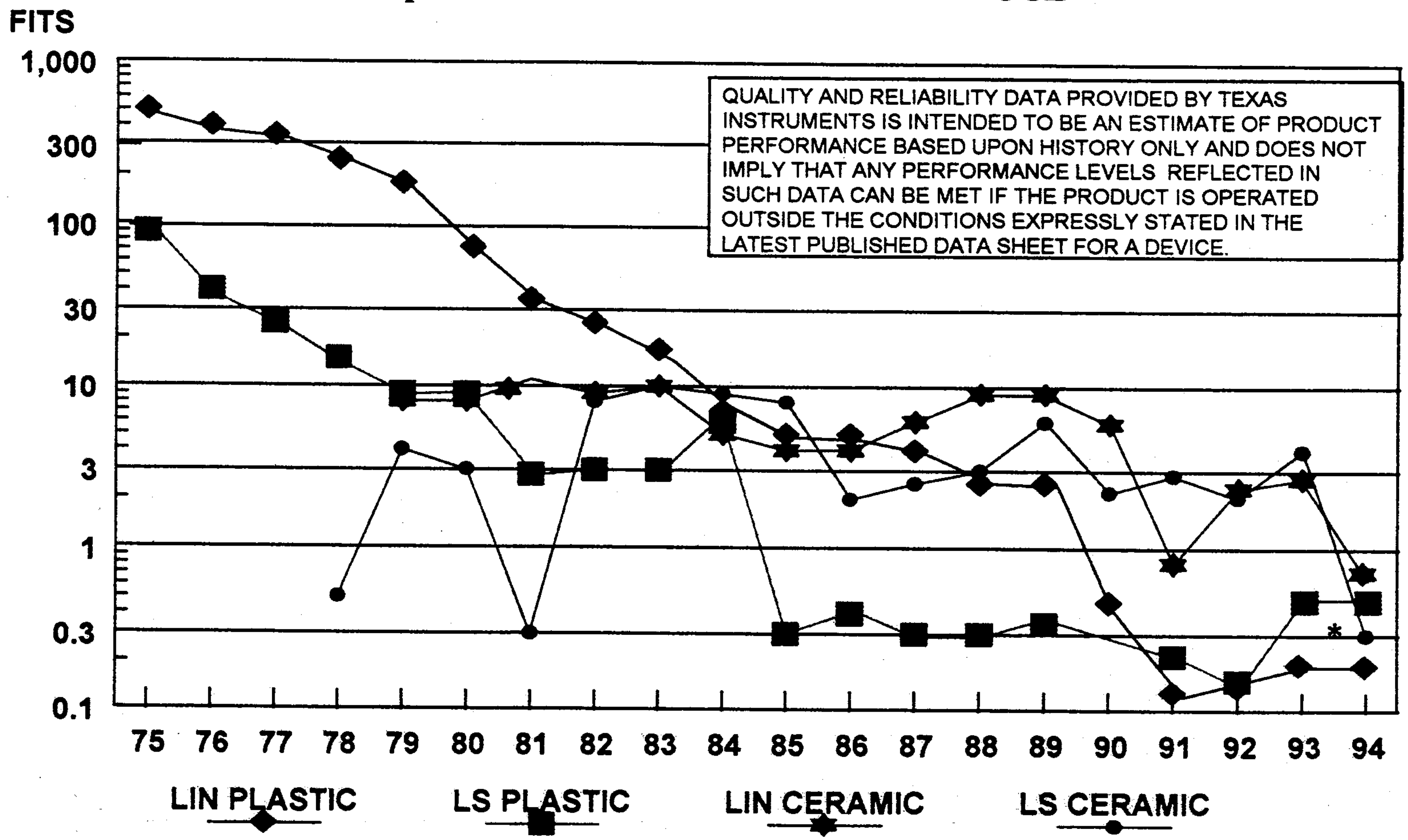
PLASTIC VS. CERAMIC OPERATING LIFE RESULTS

125C Temperature-Derated to 55C - 0.96ev 60% UCL



* Reflects recent QML data

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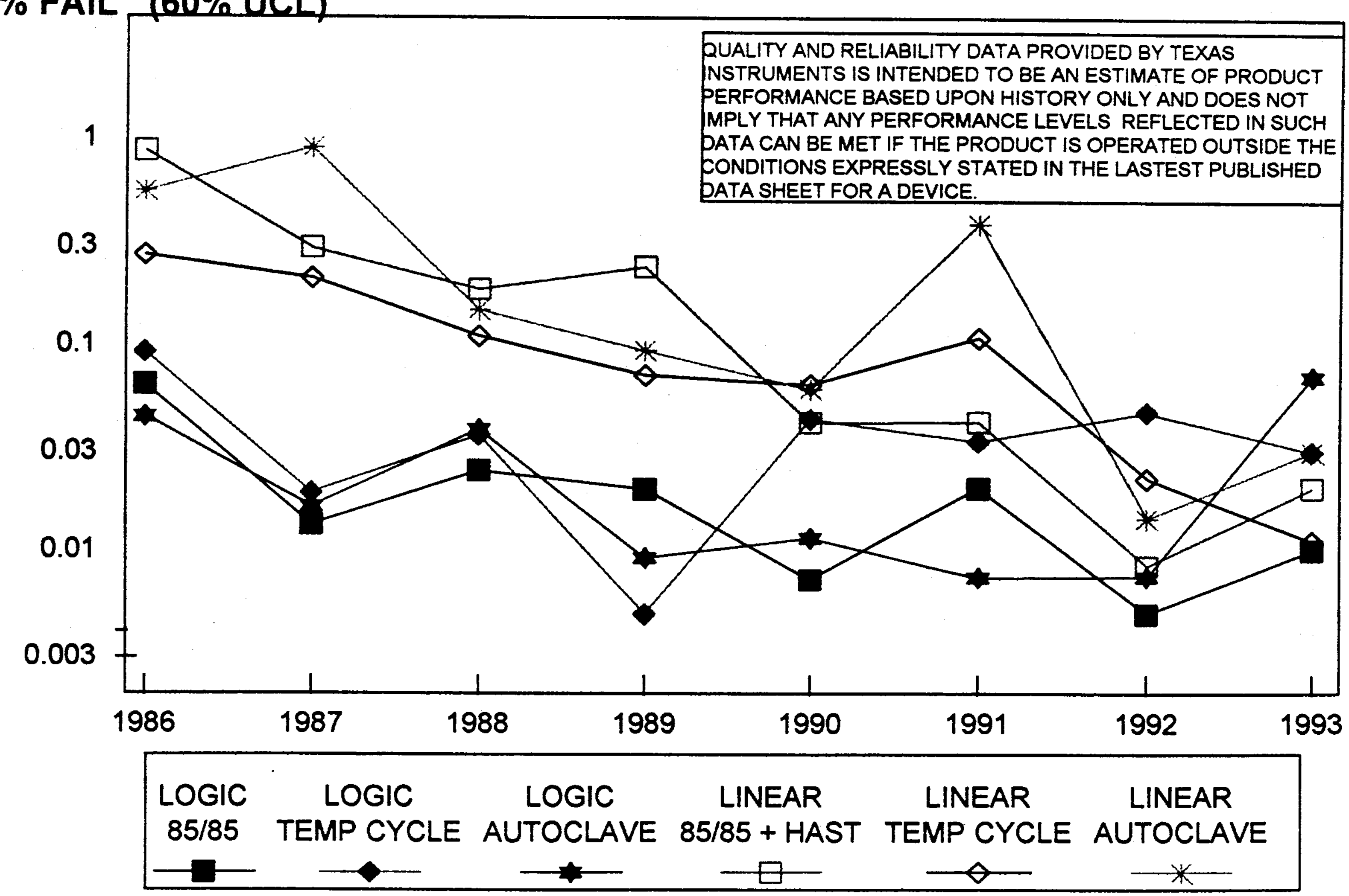
LOGIC/LINEAR SCREENING TEST DATA



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PROCESS COMPARISON

	PLASTIC	CERAMIC
WAFER	SAME	SAME
DIE ATTACH	NUMEROUS METHOD USED	GOLD OR SILVER GLASS
BOND	VARYING TEMPERATURE AND ENERGIES	ULTRASONIC
ENCAPSULATE SEAL	MANY DIFFERENT PLASTICS, MOLD COMPOUNDS	PACKAGES FROM A FEW SUPPLIERS

PLASTIC PACKAGES ARE OPTIMIZED FOR THE COMMERCIAL APPLICATION

Texas Instruments

CONCLUSIONS

- ★ A SIGNIFICANT NUMBER OF COMMERCIAL DEVICES WILL EITHER NOT WORK OR HAVE EXCESSIVE FALL OUT OVER THE MIL-TEMP RANGE
- ★ WHILE LONG TERM RELIABILITY OF PLASTIC MAY BE ACCEPTABLE IN SOME MILITARY SYSTEMS IT MAY NOT BE AS GOOD AS HERMETIC
- ★ VENDOR SELECTION IS CRITICAL IN PLASTIC REGARDLESS OF THE SYSTEM IN WHICH IT IS USED

Texas Instruments

CONCLUSIONS

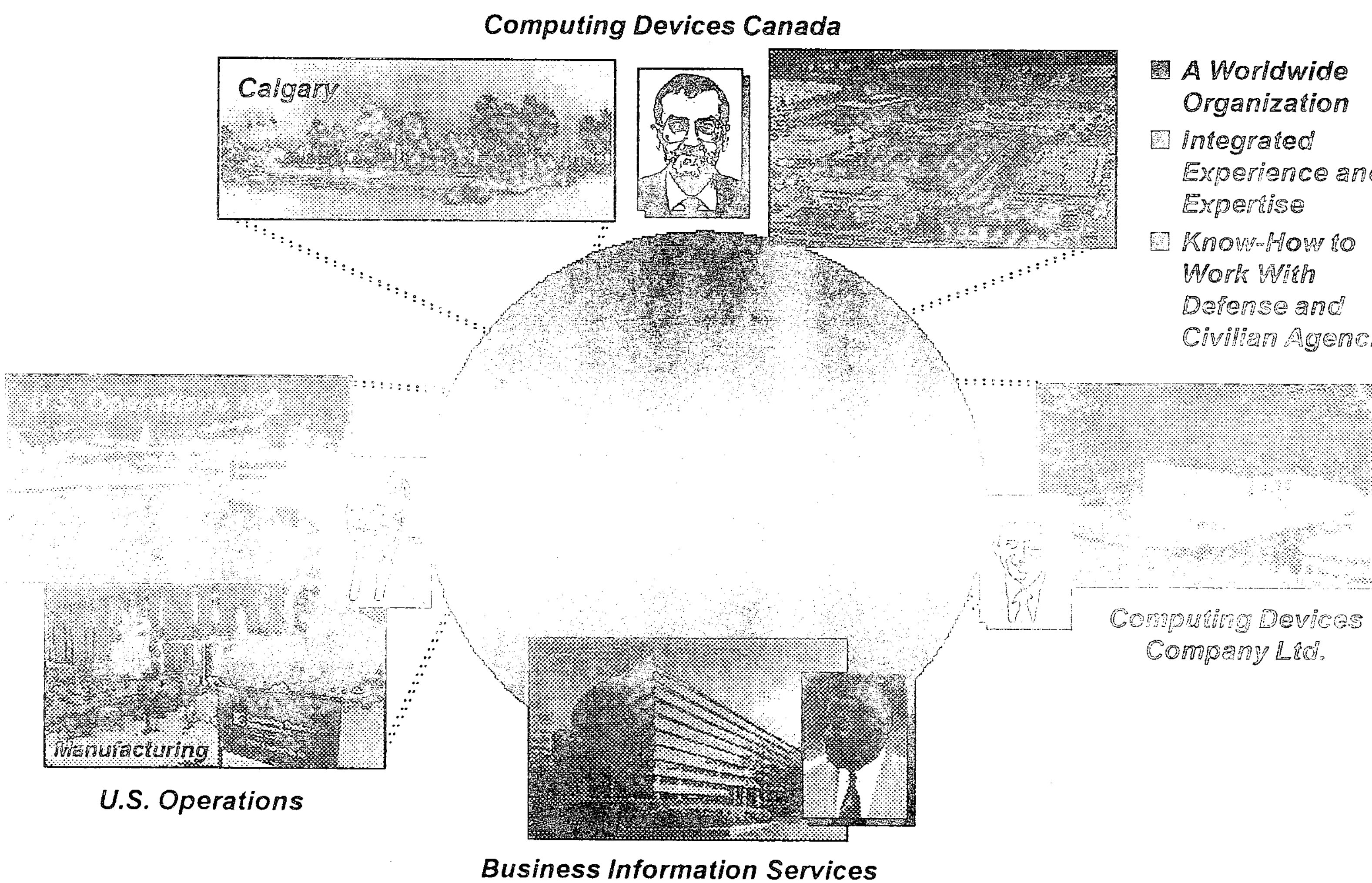
- ★ QML IS A PERFORMANCE SPEC AND SUPPORTS THE PERRY DIRECTIVE
- ★ MILITARY MARKET IS DROPPING AS A PERCENT OF TOTAL MARKET, BUT IT IS STILL $1.4B/YEAR
- ★ COMMERCIAL PLASTIC HAS LOWEST INITIAL PRICE AND CAN BE USED IN SOME MILITARY SYSTEMS
- ★ PLASTIC SURFACE MOUNT REQUIRES CAREFUL STORAGE HANDLING AND PROCESSING
- ★ SUPPORT LEVELS WILL BE SIGNIFICANTLY LOWER AS CONVERSIONS TO COMMERCIAL PLASTIC ARE MADE

THESE ARE THE ISSUES-- THE DECISION IS THE USERS

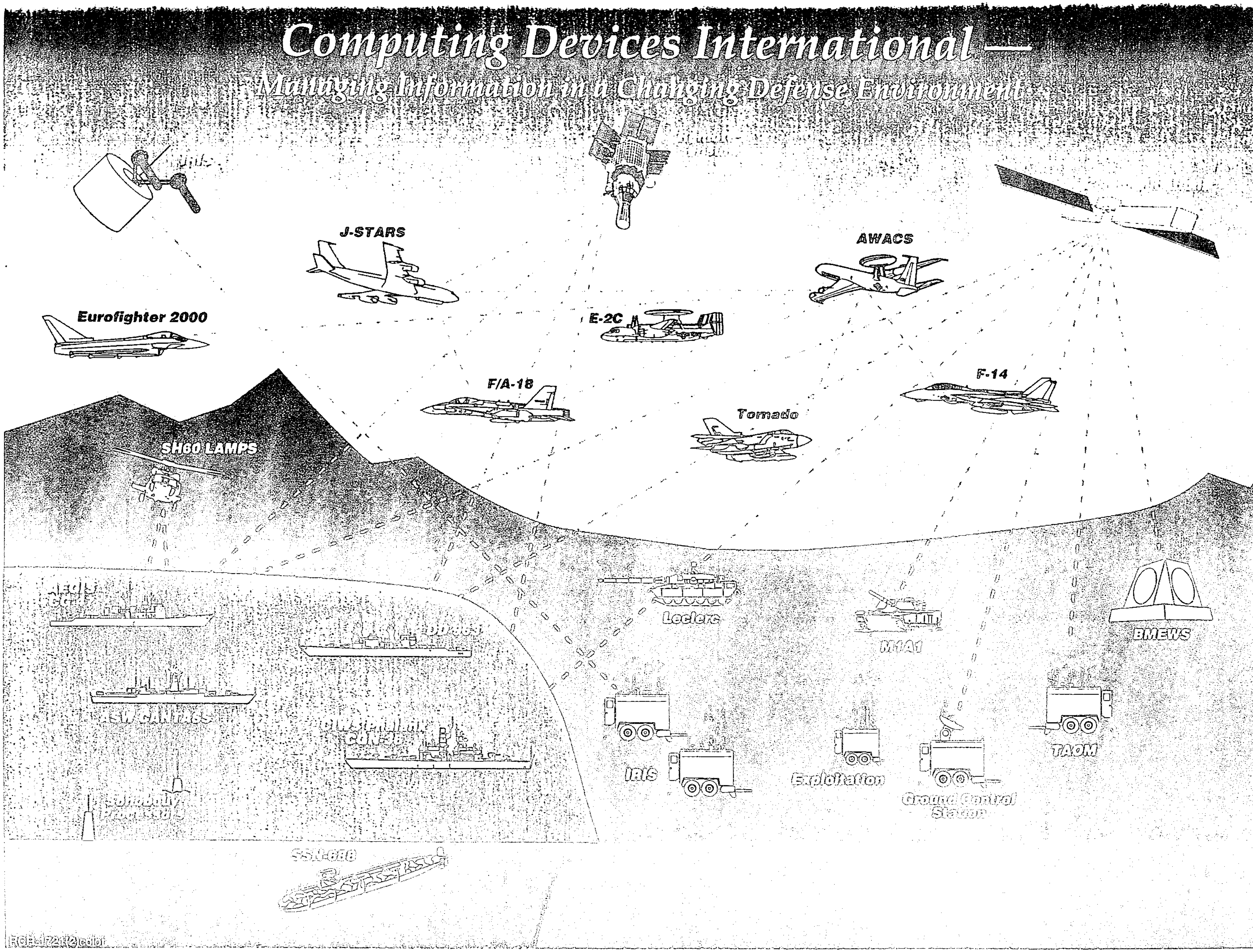
Commercial Technology for Military Applications

A Business Necessity

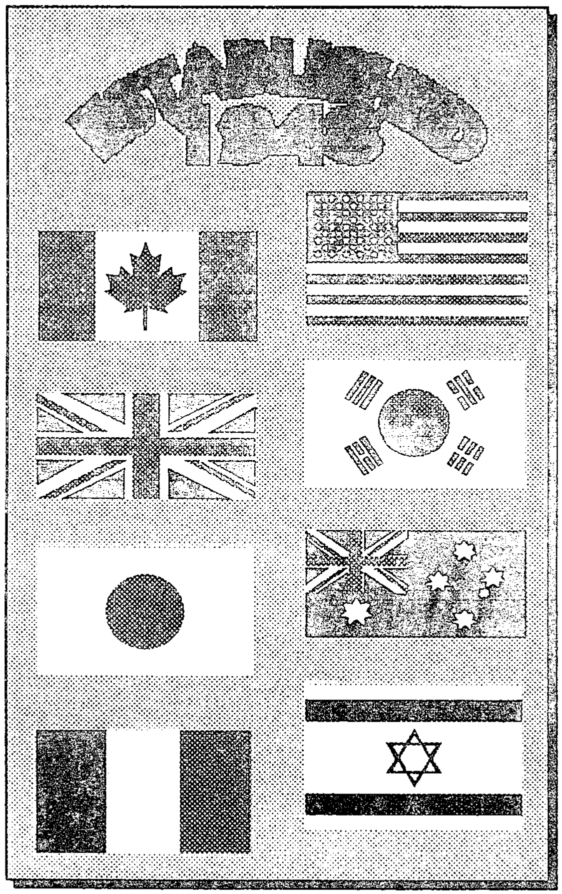
Global Scope and Presence



- A Worldwide Organization
- Integrated Experience and Expertise
- Know-How to Work With Defense and Civilian Agencies

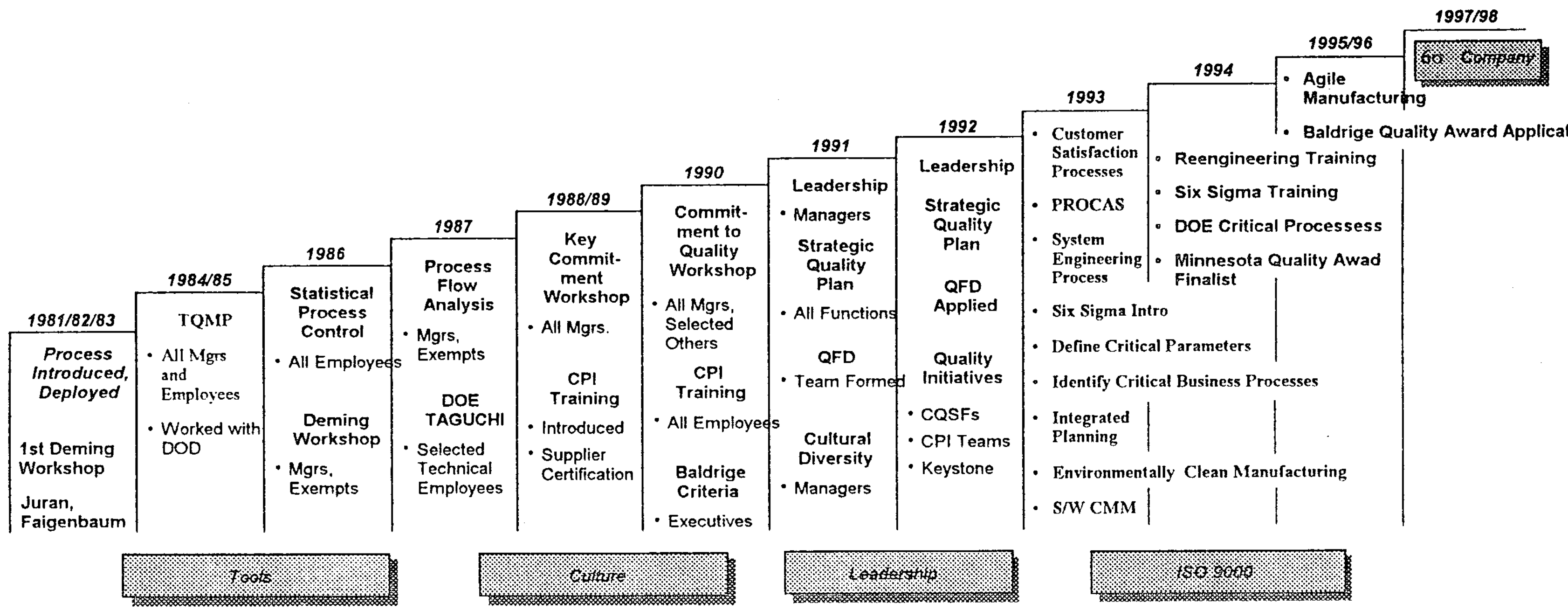

Computing Devices International —
Managing Information in a Changing Defense Environment
J-STARS
AWACS
Eurofighter 2000
E-2C
F/A-18
F-14
Tornado
SH60 LAMPS
Leclerc
M1A1
BMEWS
TAOM
IRIS
Exploitation
Ground Control Station
SSN-688

A Proven Performer

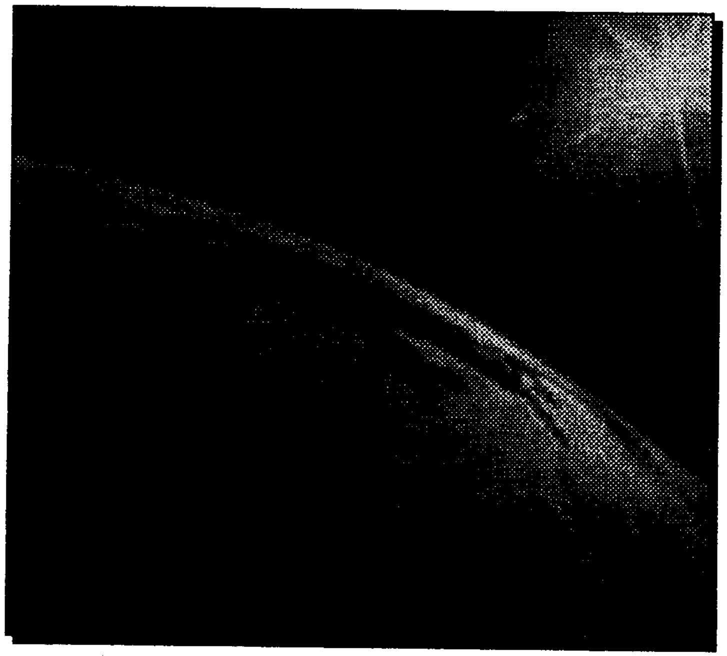


- Over 45 Years of Electronic Information Management Experience
- Hundreds of Successful Programs Worldwide
- Implementation on Thousands of Platforms, All Environments
- Technical Competence/Fast Response

Computing Devices Quality Journey



The Challenge – A Changing Defense Environment



- Creating a Strong Information Weapon
- Adapting to Worldwide Strategic Shifts
- Meeting Current and Future Tactical Requirements
- Integrating Existing and Emerging Technologies
- Helping Customers Do More With Less

Acquisition Reform

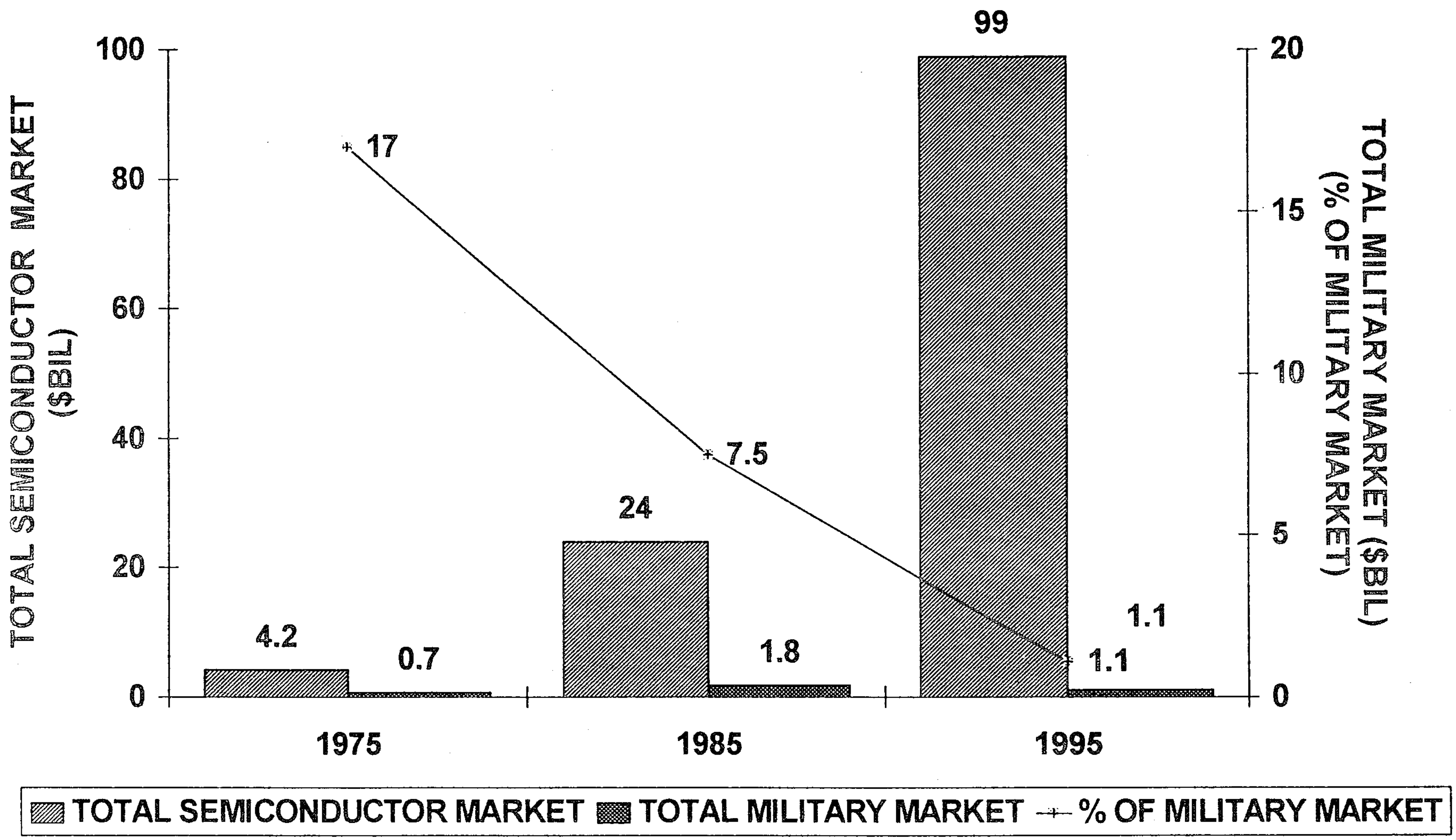
Mission

Create a national defense that derives its strength and technical superiority from an integrated commercial and military industrial base.

Goals

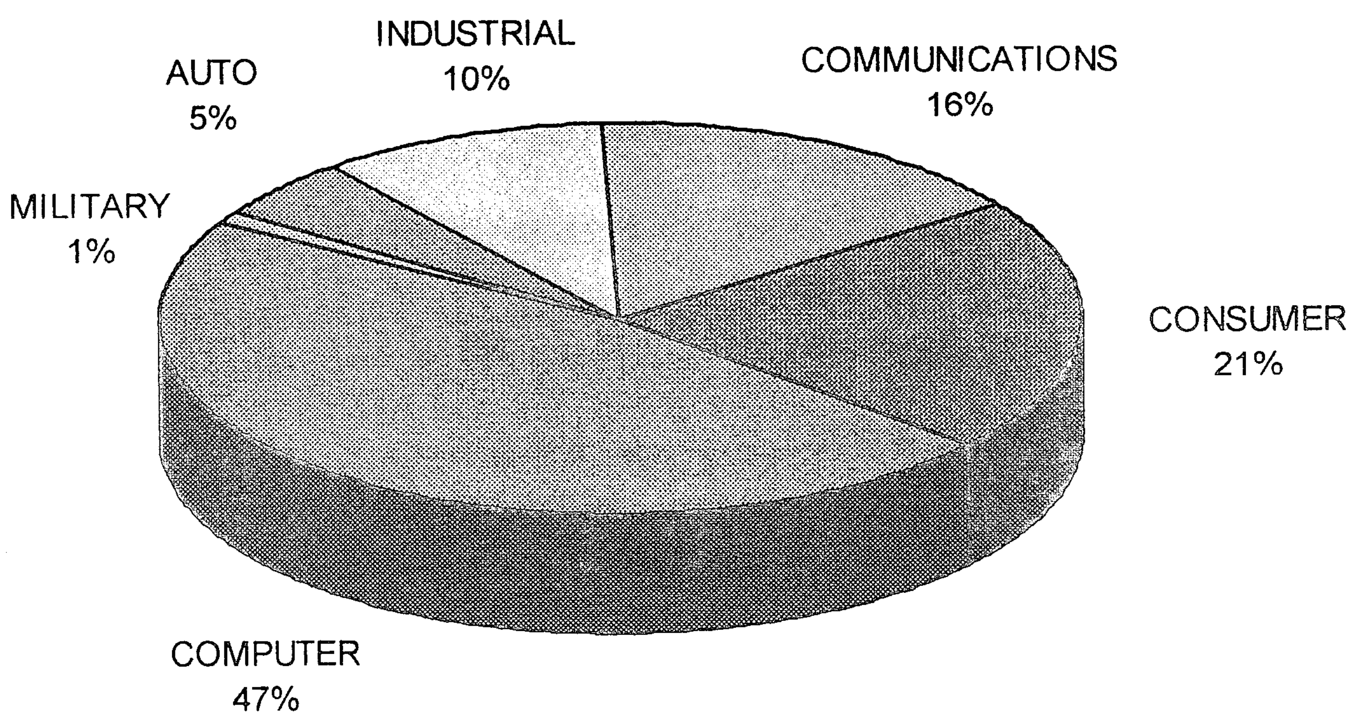
- Reduce the cost of weapon systems and material.
- Remove access barriers to state-of-the art technology.
- Facilitate defense firm's diversification into commercial markets.

DECLINING MILITARY PRESENCE



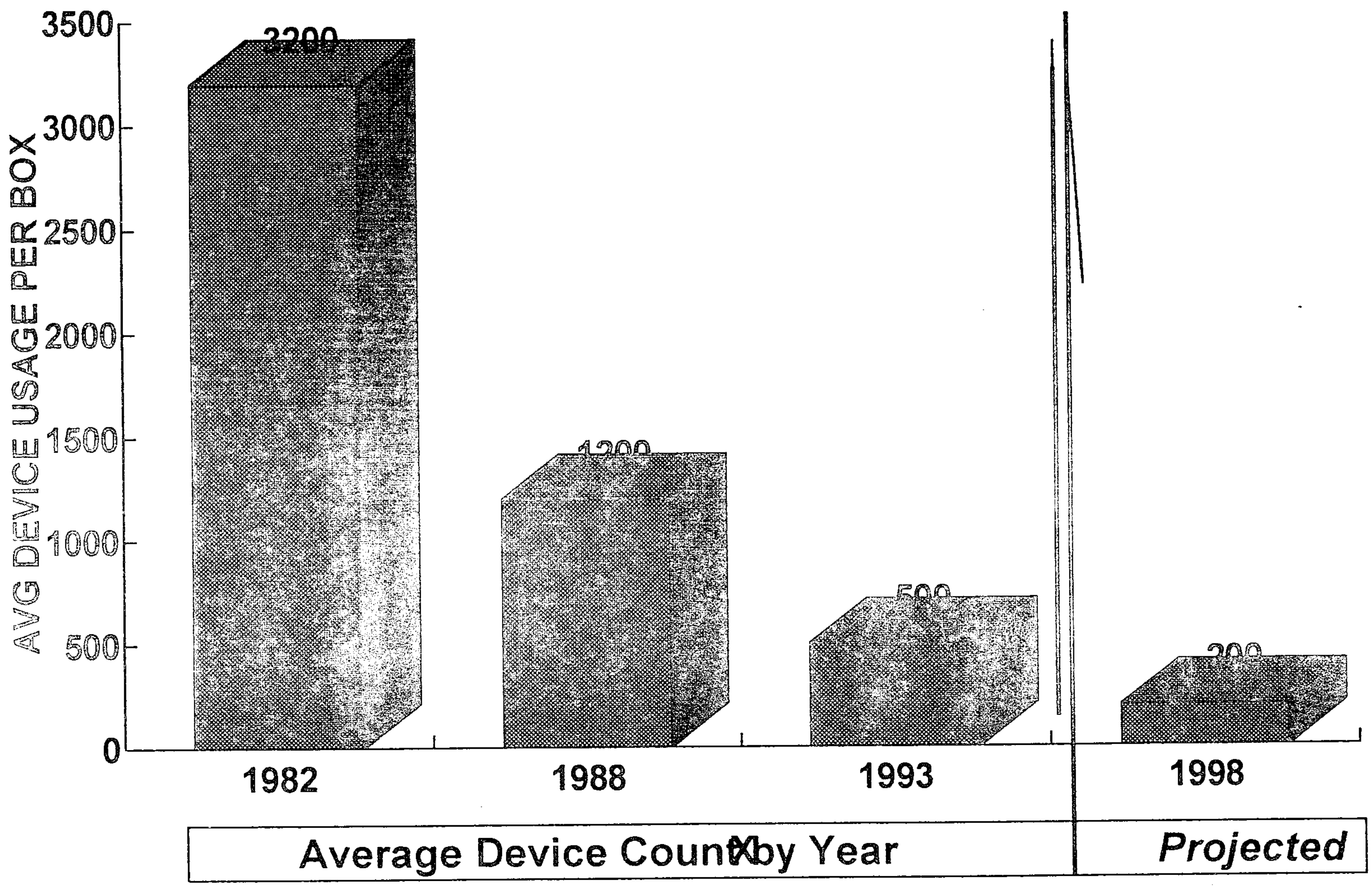
SOURCE :1994 INTEGRATED CIRCUIT INDUSTRY (ICE)/TACTech

TOTAL SEMICONDUCTOR MARKET $105.4 Billion



Source: ICE

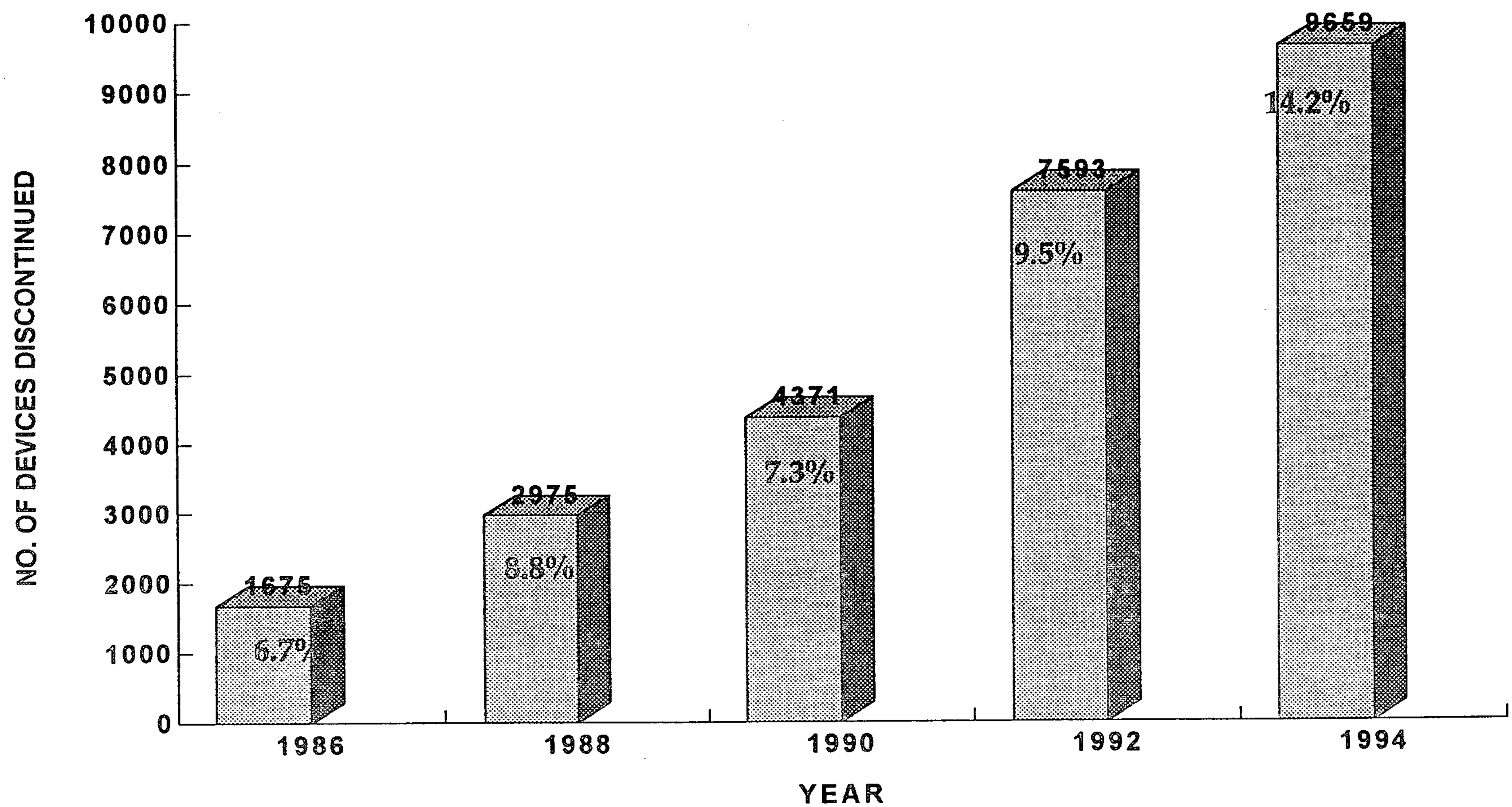
AVERAGE BOX LEVEL USAGE OF MILITARY MICROCIRCUIT DEVICES



SOURCE: MPCAG/TACTech

8/95

THE TOTAL MILITARY DEVICE * DISCONTINUANCE BY YEAR AND AS A PERCENTAGE OF TOTAL DEVICE AVAILABILITY



SOURCE: TACTech

*Includes QML, QPL, SMDs & 883 Devices

ACTIVE DEVICES
COMPONENT AVAILABILITY
COMMERCIAL vs. MILITARY
(Microcircuits, Diodes & Transistors)

■ ACTIVE COMMERCIAL DEVICE VARIATION	ACTIVE MILITARY DEVICE VARIATION
1.2 MILLION +	69,000 +
■ ACTIVE COMMERCIAL SUPPLIERS	ACTIVE MILITARY SUPPLIERS
650 +	109

Source: IHS/TACTech

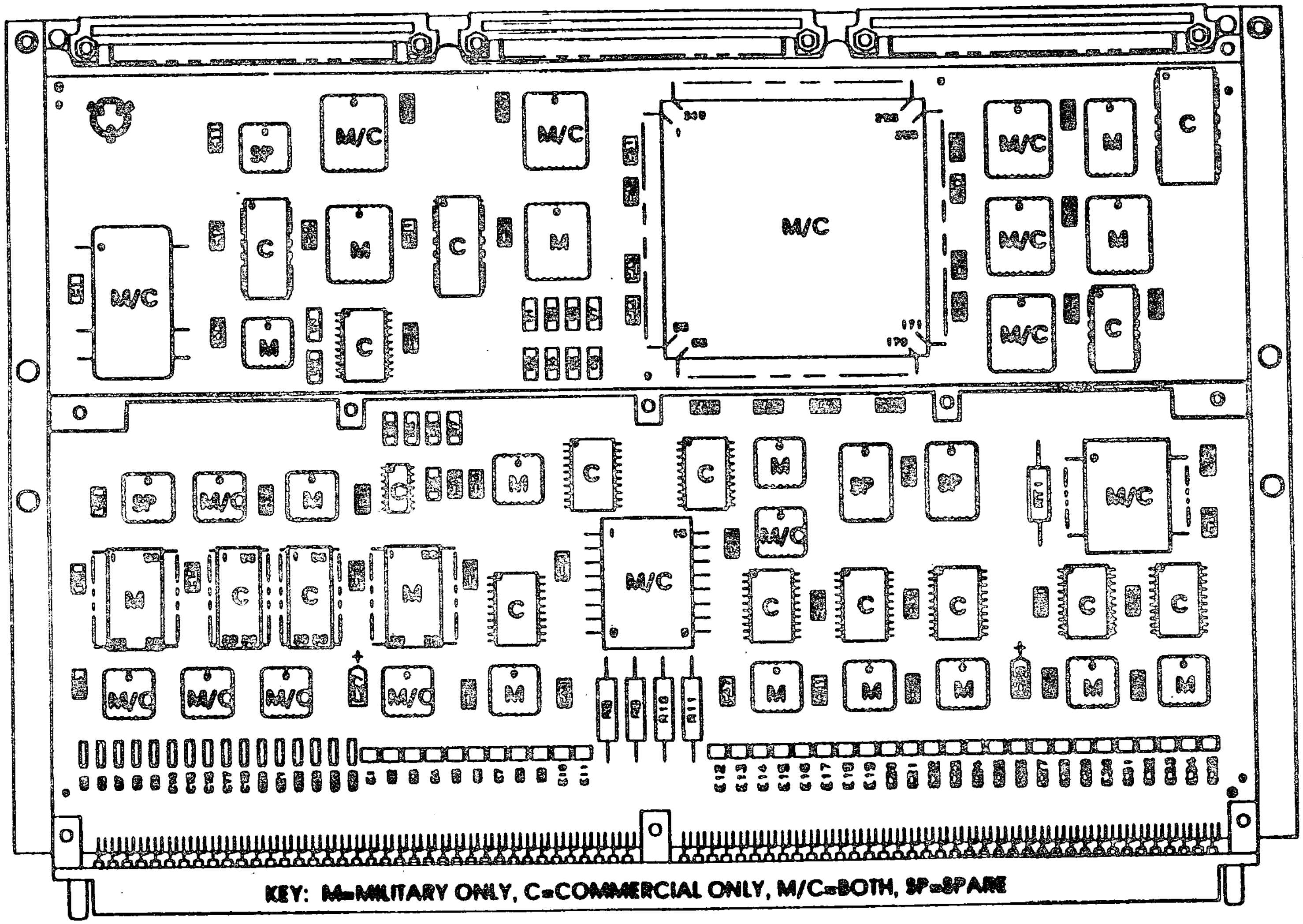
Commercial Technology

Advantages

- ❑ Affordable
  - No development costs
  - Limited testing costs
- ❑ Available
  - Multiple suppliers
  - Reduced delivery cycle
- ❑ Attractive
  - State-of-the-art technology
  - Open-system architecture

Limitations

- ❑ Requires ruggedization for most military applications
- ❑ Limited documentation support
- ❑ Steep obsolescence curve



KEY: M=MILITARY ONLY, C=COMMERCIAL ONLY, M/C=BOTH, SP=SPARE

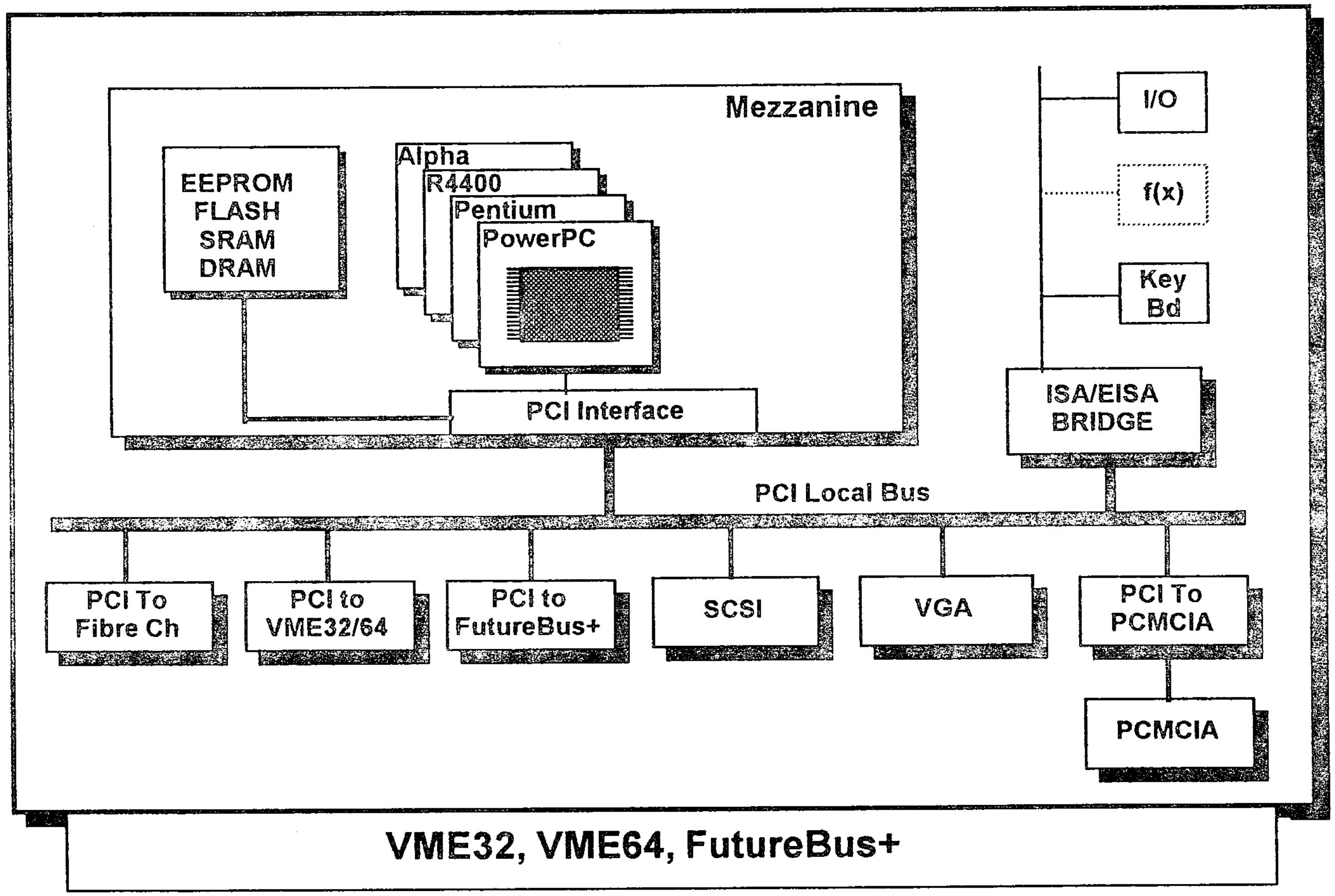
November 1995

Product Comparison

Aspect	AN/UYK-44	MK 162
Throughput	.5 - 5 MIPS	5 - 50 MIPS
Disk Capacity	None	2 Gigabytes
MTBF	5,000 hours	5,000 hours
Weight	300 pounds	190 pounds
Delivery	14 months	6 months
Price	$175,000	$90,000

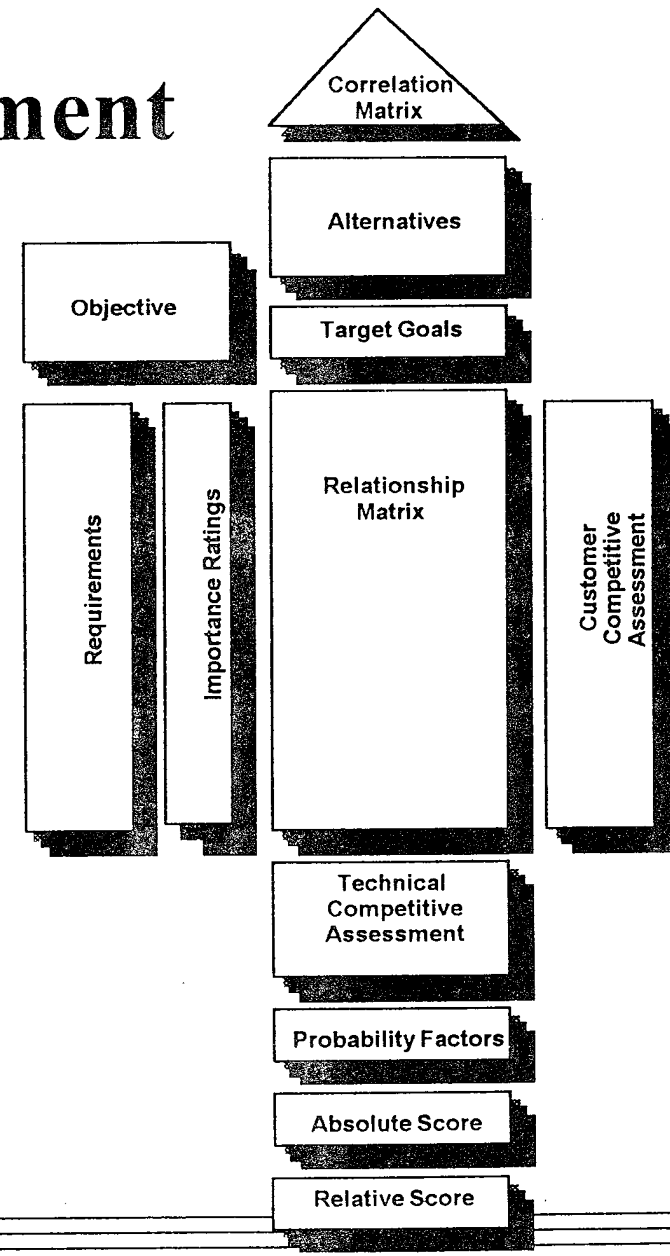
November 1995

Advanced Common Processor

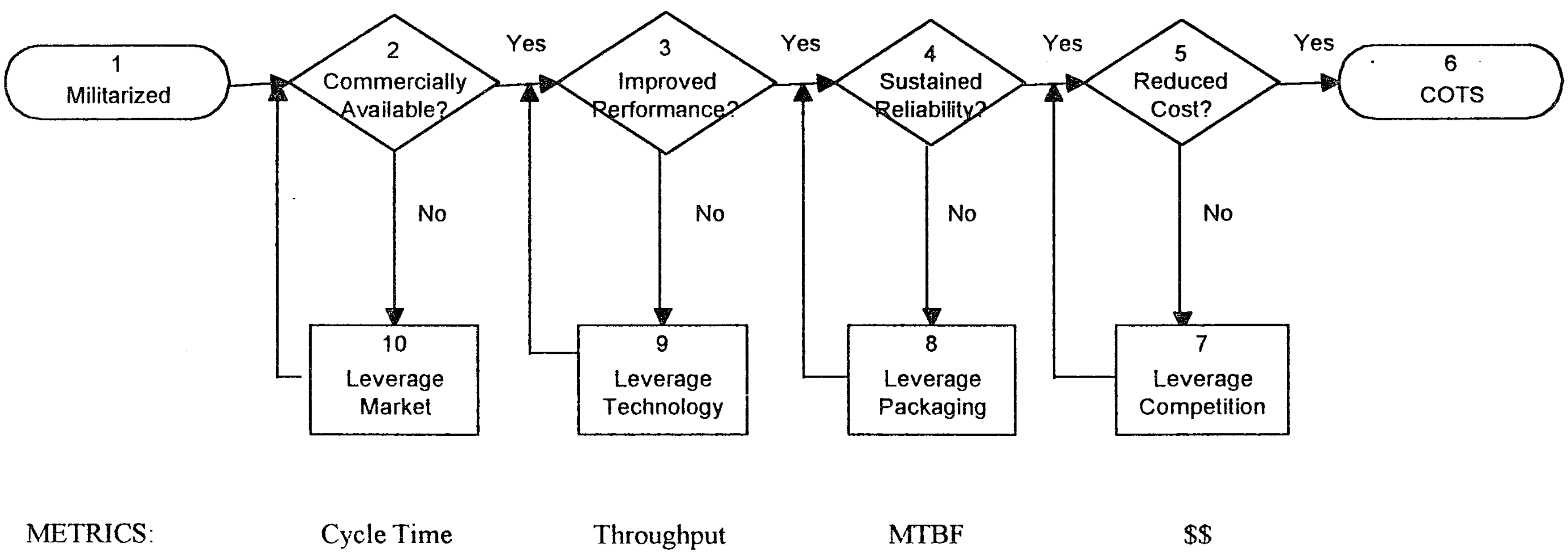


Quality Function Deployment

- Identify Objectives
- State Requirements
- Prioritize Requirements
- Define Alternatives
- Select Optimal Solution



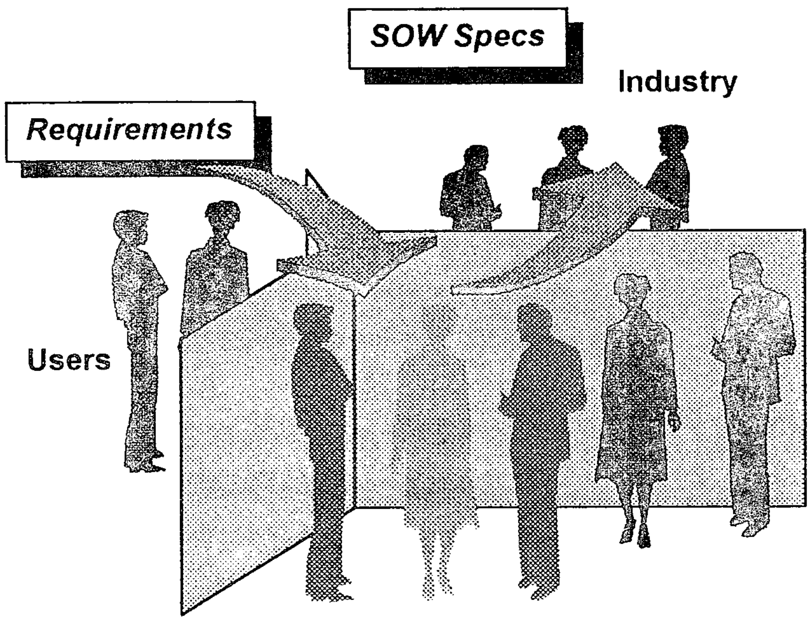
CISR™ Model



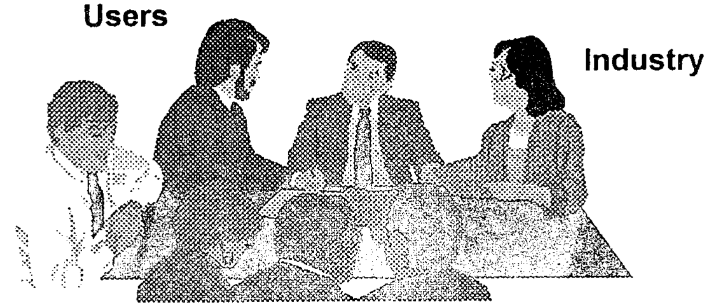
1
Militarized
2
Commercially Available?
Yes
3
Improved Performance?
Yes
4
Sustained Reliability?
Yes
5
Reduced Cost?
Yes
6
COTS
No
No
No
No
10
Leverage Market
9
Leverage Technology
8
Leverage Packaging
7
Leverage Competition
METRICS:
Cycle Time
Throughput
MTBF
$$

Paradigm Shift

From:



To:



- Multi-Disciplinary Teams
- Early Industry Involvement
- Clear, Well Understood Thresholds and Objectives
- Risk Identification, Tradeoffs, and Alternatives
- Best Value Acquisition Strategies

"WE ARE SHORT OF MONEY;

THEREFORE, WE MUST START

TO THINK"

-Lord Rutherford

SOURCE: EIA

DoD-Funded Activities in Plastic Packaging:
1. Plastic Packaging Consortium
2. Expert System for Design of Plastic Packages

Luu T. Nguyen

National Semiconductor Corp.

P.O. Box 58090   M/S 19-100

Santa Clara, CA 95052-8090

SHARP Conference, November 15-16, 1995

1. PLASTIC PACKAGING CONSORTIUM

SYNOPSIS

- **Objective**
  - ⇒ Establish an on-shore infrastructure to manufacture low-cost, high density, high performance "ruggedized" plastic packages
- **Status**
  - ⇒ Officially started December 14, 1994
  - ⇒ Ends on March 1997
- **Funding Level**: $20M with cost share >50%
- Ten member companies - NSC lead
- Program Manager: Richard Giberti (408) 721-6430 crwgsc@tevm2.nsc.com

DELIVERABLES

- Focus on *cost* and ***reliability***
- Improved reliability
  - ⇒ Unlimited shelf life - Level 1 (no dry bag)
  - ⇒ No stress-induced failures
- Increase operating temperature and thermal conductivity
- High density, low-cost substrates (PQFP & BGA applications)

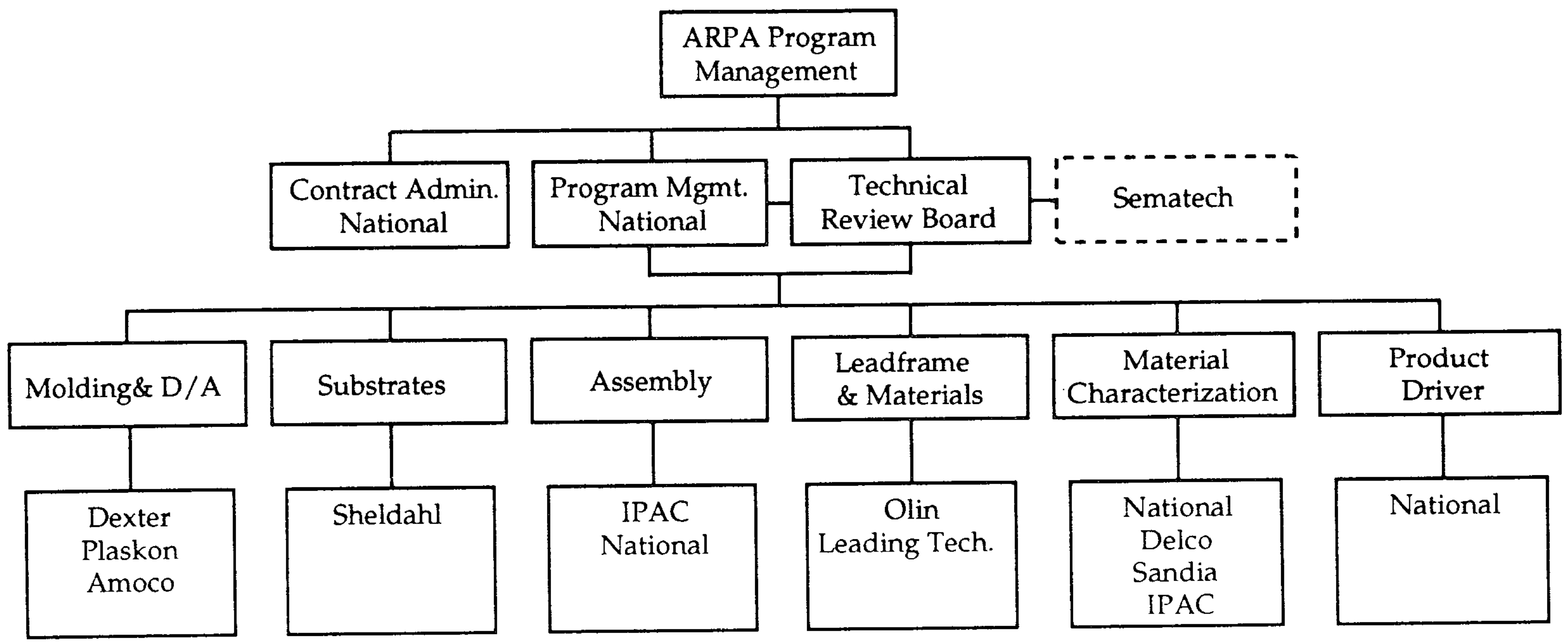
TEAM MEMBERS

- **Amoco** - Resin and molding compounds
- **Delco Electronics** - Materials characterization and system knowledge
- **Dexter** - Enhanced epoxy molding compounds, die attach materials, and flip chip underfill materials
- **Integrated Packaging Assembly Corp.** (IPAC) - QFP and BGA assembly
- **Leading Technologies** - Leadframes and tooling
- **National Semiconductor Corp.** - Materials characterization and product drivers

TEAM MEMBERS (cont.)

- **Olin Corp.** - Leadframe materials and adhesion studies
- **Plaskon** - Enhanced molding compounds
- **Sheldahl** - Design and supply high density organic substrates
- **Sandia National Laboratories** - Assembly Test Chips

ORGANIZATION



Plastic Packaging Consortium

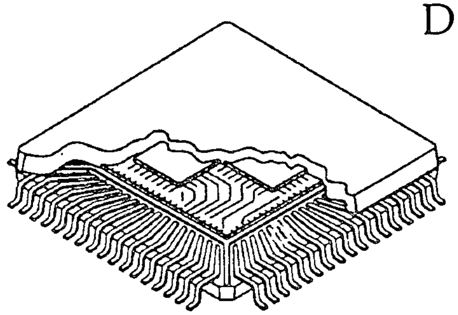
THREE INTER-RELATED FOCUS AREAS

- **Focus Area 1** - Plastic Package Ruggedization
  - ⇒ Reliability
- **Focus Area 2** - Plastic Package Thermal Enhancement
  - ⇒ High temperature operation
  - ⇒ Increased material thermal conductivity
- **Focus Area 3** - High Density Plastic Packaging
  - ⇒ Fine pitch stamped leadframes
  - ⇒ Low-cost substrates for PQFP and BGA

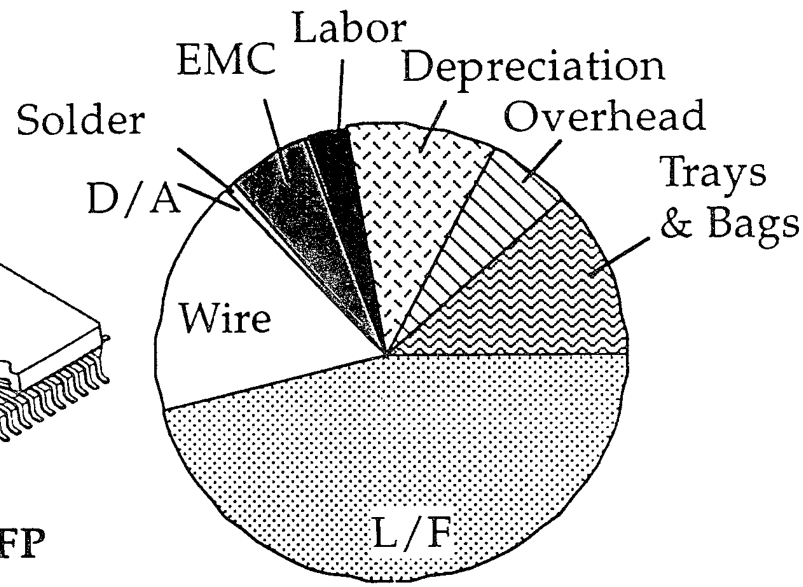
PLASTIC PACKAGE RUGGEDIZATION - GOALS

- No interfacial delamination
- "Anti-popcorning" - unlimited shelf life @ 30°C/90% RH without dry bag
- No stress-induced device failures (e.g., metal line shift, passivation cracking, dielectric cracking, or die cracking)
- High reliability
- Team cost target improvement over SIA roadmap 50% to a cost of $0.005/lead up to 300-lead PQFP

RELATIVE PACKAGING COSTS FOR A 160-LEAD PQFP



160-lead PQFP



PLASTIC PACKAGE RUGGEDIZATION - APPROACH

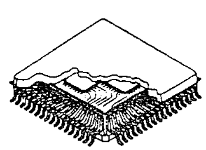
- Mold compound enhancement
- Die attach material enhancement
- Leadframe enhancement
- Reliability characterization database - Assembly Test Chips
- Technology demonstration - Product reliability & characterization

PLASTIC PACKAGE THERMAL ENHANCEMENT - GOALS

- High temperature operation (175°C)
- High thermal dissipation (θ_{ja} improvement by 50% on 160-lead PQFP to 20°C/W)
- High thermal conductivity
- Low-cost heat spreaders - Team cost target for the thermally enhanced package is $0.002/lead over the standard package of $0.007/lead
- Ruggedization

PLASTIC PACKAGE THERMAL ENHANCEMENT - APPROACH

- Molding compound temperature enhancement
- Die attach material thermal conductivity and voiding enhancement
- Leadframe material enhancement
- Heat spreader development and assembly automation
- Reliability characterization database - Assembly Test Chips
- Technology demonstration - Product reliability & characterization



HIGH DENSITY PLASTIC PACKAGING - GOALS

- Fine pitch, stamped, low-cost leadframes - Two packages are addressed: 1. 160-lead PQFP with 6.0 mil internal pitch & 4.0 mil lead flat; 2. 240-lead PQFP with 7.0 mil internal pitch & 4.0 mil lead flat
- High density, low-cost substrates (interposers) for PQFP - Interposer cost adder $0.10 for 160-lead PQFP
- High density, low-cost substrates for BGA - Substrate cost <$0.40/in^2
- Minimal or zero warpage of BGA
- Reworkable, low stress underfill for flip chip BGA

HIGH DENSITY PLASTIC PACKAGING - APPROACH

- Integration of interposer to leadframe
- Ruggedization
- 160-lead & 240-lead PQFP fine pitch stamped leadframes
  - ⇒ 6.0 mil internal pitch for 160-lead PQFP
  - ⇒ Tool material development
- Interposer/leadframe integration
  - ⇒ Thermal compression
  - ⇒ Conductive adhesives
  - ⇒ High temperature solder
- Low-cost substrate

HIGH DENSITY PLASTIC PACKAGING - APPROACH

- Flip chip plastic BGA
  - ⇒ Molding compound for BGA - low warpage
  - ⇒ Reworkable, low stress underfill material
  - ⇒ BGA flip chip low-cost substrate (design & materials)
- Reliability characterization database - Assembly Test Chips
- Technology demonstration - wirebond and flip chip

SUMMARY

- Upon completion of the Program, we will have:
  - ⇒ A viable cost-reduced domestic plastic packaging infrastructure
  - ⇒ Established a promising new technology base
- Technology transfer through publications, reports, and workshops

PLAN- PLASTIC PACKAGE RUGGEDIZATION

- Three iterations of materials for complete characterization & testing over the 1st 16 months of the Program
- Each round of materials will be characterized for mechanical & manufacturability properties & reliability performance with test chips
- Establish a characterization database
- Use optimized materials to assemble product drivers for technology demonstration

SCHEDULE - PLASTIC PACKAGE RUGGEDIZATION

- Materials delivery
  - ⇒ Scouting samples (1st iteration) 8/1/95
  - ⇒ Improved samples (2nd iteration) 1/15/96
  - ⇒ Optimized samples (3rd iteration) 5/1/96
  - ⇒ Optimized material selection 7/1/96
  - ⇒ Technology demo build 8/1/96

SCHEDULE - PLASTIC PACKAGE RUGGEDIZATION (cont.)

- Materials suppliers (scouting, improved, optimized samples)
  - ⇒ Molding compound - *Amoco, Dexter, Plaskon*
  - ⇒ Die attach material - *Dexter*
  - ⇒ High strength leadframe alloy - *Olin*
  - ⇒ Leadframe adhesion enhancement
    - → Optimized "A2" - *Olin*
    - → Optimized plating - *Leading Tech.*
  - ⇒ Adhesion to polyimide guard ring - *Leading Tech.*
  - ⇒ Die coatings - *Amoco*
  - ⇒ Assembly capability - *IPAC, National*

SCHEDULE - PLASTIC PACKAGE RUGGEDIZATION (cont.)

- Materials characterization
- Completion schedule
  - ⇒ Scouting samples 11/95
  - ⇒ Improved samples 4/96
  - ⇒ Optimized samples 8/96
- Mechanical & Physical - *Delco, Plaskon, Dexter, Olin, Leading Tech.*
- Assembly manufacturing - *IPAC, National*
- Reliability - *Sandia, National*

SCHEDULE - PLASTIC PACKAGE RUGGEDIZATION (cont.)

- Test chips will be developed and supplied by Sandia and National
- Technology demonstration
  - ⇒ 160-lead Super I/O™ (1) - *National*
  - ⇒ 240-lead Super I/O™ (2) - *National*
- Die attach material

PLAN- PLASTIC PACKAGE THERMAL ENHANCEMENT

- Similar to Focus Area 1 - Plastic Package Ruggedization
- Design and demonstration of automated tooling for the production of heat sink attachment

SCHEDULE - PLASTIC PACKAGE THERMAL ENHANCEMENT

- Materials delivery

⇒ Scouting samples (1st iteration)	8/1/95
⇒ Improved samples (2nd iteration)	1/15/96
⇒ Optimized samples (3rd iteration)	5/1/96
⇒ Optimized material selection	7/1/96
⇒ Technology demo build	8/1/96

SCHEDULE - PLASTIC PACKAGE THERMAL ENHANCEMENT (cont.)

- Materials suppliers (scouting, improved, optimized samples of both high thermal conductivity & high temperature operation compounds)
  - ⇒ Molding compound - *Dexter, Plaskon*
  - ⇒ Die attach material - *Dexter*
  - ⇒ High thermal conductivity leadframe alloy - *Olin*
  - ⇒ Heat sink attachment - *Leading Tech.*
  - ⇒ Assembly capability - *IPAC, National*

SCHEDULE - PLASTIC PACKAGE THERMAL ENHANCEMENT (cont.)

- Test chips will be developed and supplied by Sandia and National
- Technology demonstration
  - ⇒ 160-lead LAN - *National*
  - ⇒ High temperature operation chip - *National*

PLAN- HIGH DENSITY PLASTIC PACKAGING

- Similar to Focus Area 1 - Plastic Package Ruggedization
- Three different projects being addressed
  - ⇒ Fine pitch leadframe stamping tool development
  - ⇒ Multi-chip packaging with low-cost substrate in PQFP
  - ⇒ Multi-chip packaging with substrate in BGA

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING

- Fine pitch stamped leadframes will be modeled, designed, and produced for 160-lead and 240-lead PQFP

⇒ Frame design - *LT*	10/23/95
⇒ Stress reduction process - *LT, Olin*	12/4/95
⇒ Punch material evaluation - *LT*	10/5/95
⇒ Tool prototyping - *LT*	
→ 160-lead	9/10/96
→ 240-lead	6/18/96

⇒ Technology demonstration of 160-lead PQFP as described in Focus Area 1

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING (cont.)

- Multi-chip PQFP efforts will use a low-cost Sheldahl substrate assembled in a PQFP leadframe
- Three efforts:
  - ⇒ Test chip development
  - ⇒ Leadframe integration
  - ⇒ Development of multi-chip substrate

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING (cont.)

- Test chip development (developed to study the interaction of Sheldahl substrate with other plastic packaging materials, and to evaluate the leadframe integration process)
  - ⇒ Design reviews 2/2; 3/30/95
  - ⇒ First samples assembled and tested 11/20/95

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING (cont.)

- Leadframe integration
  - ⇒ Three attachment methods to be evaluated:
    - →Au/Au
    - →Au/Ag
    - →Au/Sn
    - →Au/Solder (90Sn/10Pb)
    - →Pd (substrates) with previous options
  - ⇒ Evaluation report 11/20/95
  - ⇒ Process optimization 1/15/96
- Development of multi-chip substrate 12/1/96

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING (cont.)

- Development of multi-chip substrate
  - ⇒ Materials delivery
    - →Scouting samples (1st iteration) 9/15/95
    - →Improved samples (2nd iteration) 2/16/96
    - →Optimized samples (3rd iteration) 5/17/96
    - →Optimized material selection 7/15/96
    - →Technology demo build 8/15/96
  - ⇒ Materials suppliers (scouting, improved, optimized samples) - *Dexter, Plaskon*

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING (cont.)

⇒ Materials characterization
  - Scouting 1/96
  - Improved 5/96
  - Optimized 8/96
  - →Mechanical & Physical - *Delco, Plaskon, Dexter, Sheldahl*
  - →Assembly & manufacturing - *IPAC, Sheldahl, National*
  - →Reliability - *Sandia, National*

SCHEDULE - HIGH DENSITY PLASTIC PACKAGING (cont.)

⇒ Underfill material (scouting & optimized) - *Dexter*

⇒ Substrate material - *Sheldahl*

⇒ BGA capability (molds ordered) - *IPAC, National*

⇒ Test chips developed and supplied by Sandia. Test chips from the "Low-Cost Flip Chip Consortium TRP" will also be used.

⇒ Final technology demo with a LAN chip set

2. Expert System for Design of Plastic Packages

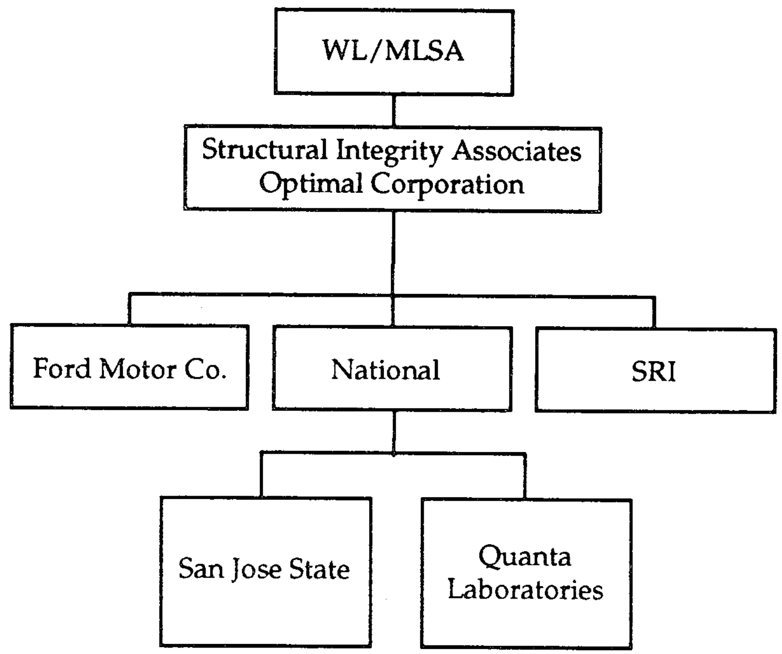
SYNOPSIS

- **Objective**
  - ⇒ Establish an Expert System for Design of Plastic IC Packages against latent moisture-induced defects
- **Status**
  - ⇒ Officially started May 15, 1994
  - ⇒ Ends on December 1996
- **Funding Level**: $700K - SBIR Phase II
- Three companies - Structural Integrity Associates lead
- Program Manager: An-Yu Kuo (408) 927-8600 optimal1@ix.netcom.com

DELIVERABLES

- Develop a rule-based Expert Design System for Plastic Packages
  - ⇒ Collect material data base
  - ⇒ Collect popcorn failure data
  - ⇒ Establish a failure mechanism and criterion
  - ⇒ Validate by finite element modeling
  - ⇒ Incorporate database and models into the Expert Design System

ORGANIZATION



SI/OPTIMAL - WORKSCOPE

- Automatic mesh generator
- Assessment of coupling effects
- Numerical algorithm for moving vaporization fronts
- Assessment of nonlinear and time-dependent effects
- Integration and implementation of Expert Design System
- Report and manuals

SI/OPTIMAL - STATUS

- Mesh generation of all EIA/JEDEC plastic packages
  - ⇒ Form factors: DIP, SOP, PLCC, PQFP, PGA, BGA
  - ⇒ Standards: JEDEC, EIAJ
  - ⇒ Components: Die, Die attach, Die attachment pad, Die coating, Leadframe, Molding compound, Solder, Board, Metal Traces
  - ⇒ Parametric input and modeling
- Hardware/software specification

NATIONAL - WORKSCOPE

- Evaluate the popcorning threshold factor of different packages
- Determine the failure criterion for various interfaces in plastic packages
- Determine the criterion for crack propagation in three EMCs as a function of T and moisture content
- Evaluate the hygroscopic behavior of the EMCs
- Evaluate the popcorning phenomenon as a function of ramp rate and peak temperature
- Evaluate the effect of preconditioning on package reliability

NATIONAL - STATUS

- **Task 1:** Evaluate the popcorning threshold factor of different packages
  - ⇒ Ongoing for different package families and lead count, e.g., for Quad Packages
    - →PLCC - 20, 28, 44, 52, 68, 84
    - →PQFP - 44, 48, 52, 64, 80, 100, 120, 128, 144, 160, 208
    - →TQFP - 32, 48, 64, 80, 100, 144, 208
    - →GaAs packages *(with Quanta Labs)*
- Check for interface delamination and external cracking
- Temperature and humidity preconditioning

NATIONAL - STATUS (cont.)

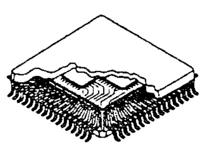
- **Task 2**: Determine the failure criterion at interfaces *(with SJSU)*
  - ⇒ Pull tests for characterizing delamination strength at interfaces
  - ⇒ Shear tests for delamination shear strength
  - ⇒ 3-point bending with interfacial crack
  - ⇒ Interfacial integrity characterization by SAT

NATIONAL - STATUS (cont.)

- Task 3: Determine the criterion for crack propagation for three EMCs *(with SJSU)*
  - ⇒ Standard formulation (low pin count packages)
  - ⇒ Low-stress formulation (high pin count packages)
  - ⇒ Anti-popcorn formulation (moisture sensitive, high value-added packages)
  - ⇒ Temperature range up to 260°C
  - ⇒ Moisture content: 0% to past critical moisture level
  - ⇒ 3-point bending in T/RH environmental chamber for fracture toughness characterization

NATIONAL - STATUS (cont.)

- **Task 4**: Evaluate the hygroscopic behavior of the EMCs
  - ⇒ Moisture diffusion coefficient
  - ⇒ Hygro-swelling coefficient
  - ⇒ Mass & energy transport coupling coefficients
  - ⇒ "Best effort" collaboration with NIST to elucidate the fundamental mechanism of moisture diffusion in EMC & moisture behavior at interfaces

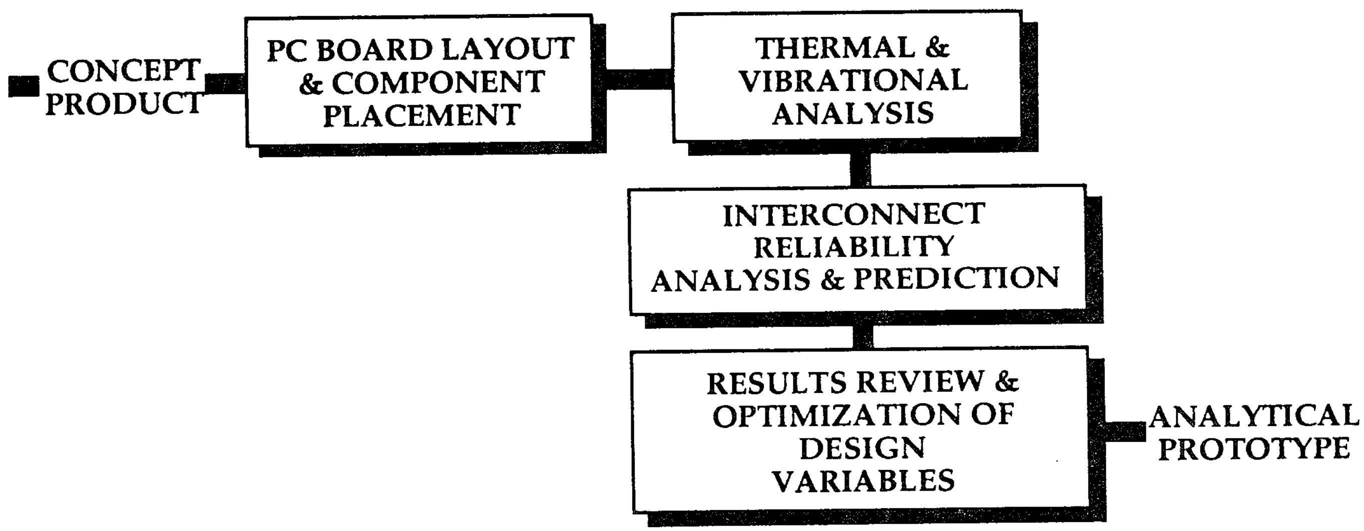


NATIONAL - STATUS (cont.)

- **Task 5**: Study the effects of heating/reflow profile and method on popcorning
  - ⇒ Ramp rate
  - ⇒ Peak temperature and duration
  - ⇒ When does popcorning occur?
- **Task 6**: Evaluate the effect of interfacial delamination from preconditioning on package reliability
  - ⇒ Candidate packages (TBD)
  - ⇒ Reliability testing (TBD)

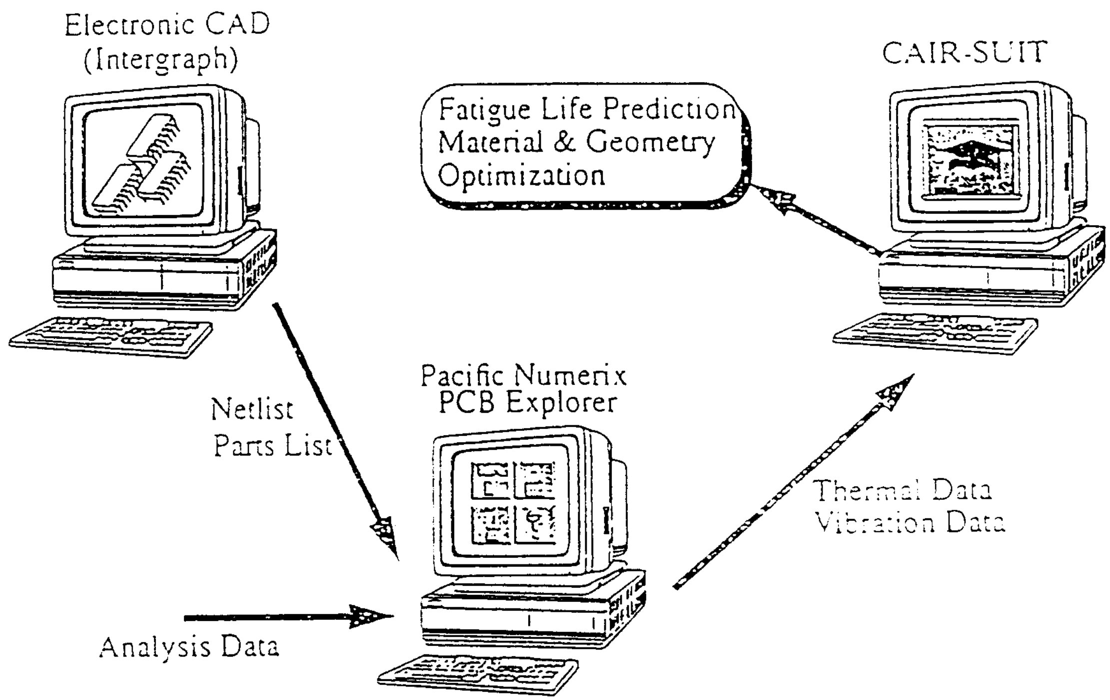
FORD - WORKSCOPE

- Provide the shell for the Expert Design System based on Ford's CAIR (Computer Aided Interconnect Reliability)



Expert System for Design of Plastic Packages

CAIR SYSTEM ARCHITECTURE



Expert System for Design of Plastic Packages

The Reliability of Plastic Encapsulated Microcircuits

WILLIAM K. DENSON
Reliability Analysis Center

SHARP COMPONENTS WORKSHOP

November 15, 16, 1995

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Outline

- Background
- Purpose
- Summary of data
- Reliability model

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Background on PEM Usage

Pros	Cons
• Availability	• Uncertain long term reliability
• Weight	• Uncertain reliability in harsh environments
• Cost	• Lack of Quality/Reliability standards
	• Lack of Empirical Data

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Purpose

- Collect PEM data
  - Field
  - HAST
  - 85/85
  - Temperature Cycling
  - Life
  - Failure Mode/Mechanism
- Analyze data
- Develop model

Goals of this Model

- Accurately predict the field failure rate of PEMs under a wide variety of use conditions
- Provide adequate sensitivity as a function of the predominant reliability drivers
- Predict the failure rates as a function of most operating scenarios
- Include tailoring provisions that allow the use of empirical data (if available) on a specific product or product line to better predict field reliability.

Summary of 1992 Field Failure Data

	Device Type	Application: Ground Benign (G_B)	Application: Commercial Airborne (A_I)	Application: Automotive Underhood (G_M)
Failure Rates (Failures/ Million op-hours)	Linear	.0030	.054	.32
	Digital SSI/MSI	.00097	.01	.11
	Memory/Microprocessor	.0023	.14	.13
Data Attributes	Operating Hours	4.5×10^{11}	2.2×10^{9}	8.0×10^{10}
	Failures	57,274	98	18,830
	Dates	1980 - 1992	1992	1991 - 1993

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Summary of Test Data

TEST TYPE	Lognormal Characteristic Life Mean	AverageWeibull Shape Parameter (β)
HAST (AVERAGE CONDITIONS = 137°C, 85% RH)	1595H	4.5
AUTOCLAVE	665H	–
85°C/85% RH	6611H	–
HIGH TEMP STORAGE (200 °C)	1065H	4.6
TEMPERATURE CYCLING (AVERAGE $\Delta T = 215$)	3745C	3.5
Life Test	963,167H	.93
H = Hours C = Cycles		

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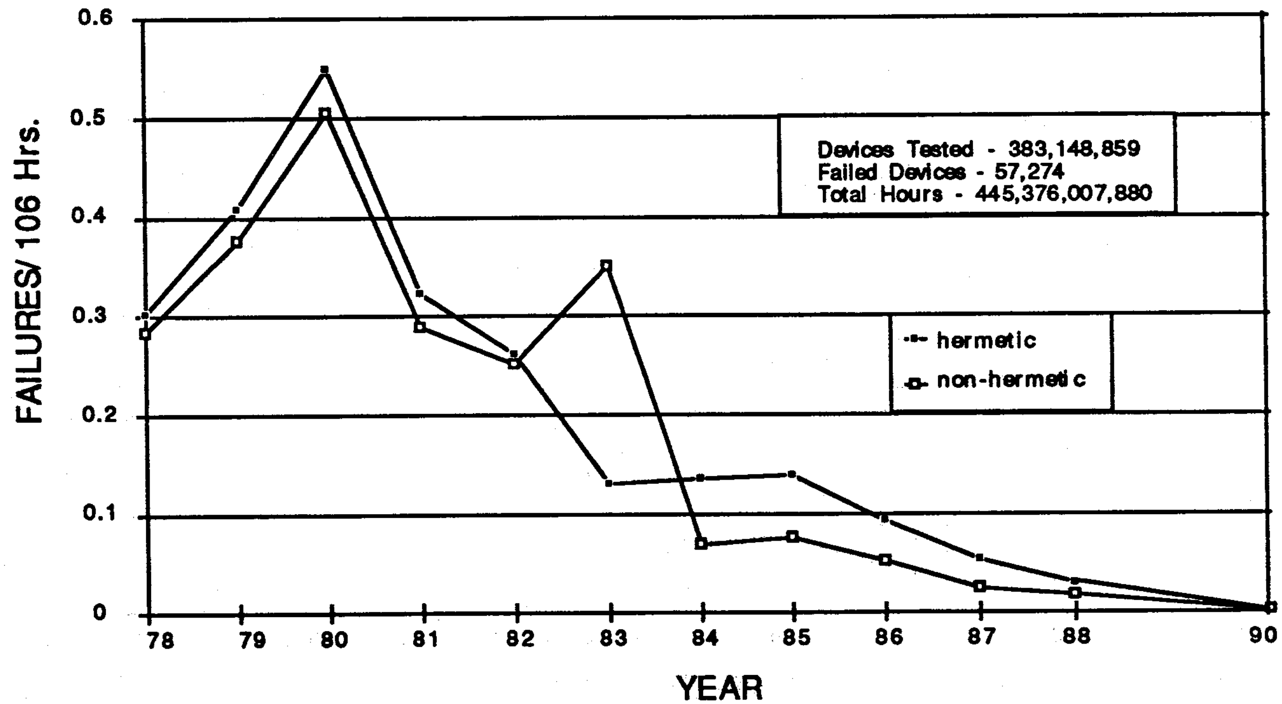
Ground Benign Failure Rates of Hermetic and Nonhermetic Devices



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Basic Model Form

$$\lambda_P = \lambda_O + \lambda_E + \lambda_{TC}$$

λ_p = **Predicted failure rate in F/10^6 calendar hours**

λ_o = **Failure rate resulting from operational stresses**

λ_E = **Failure rate resulting from environmental stresses**

λ_{TC} = **Failure rate resulting from temperature cycling stresses**

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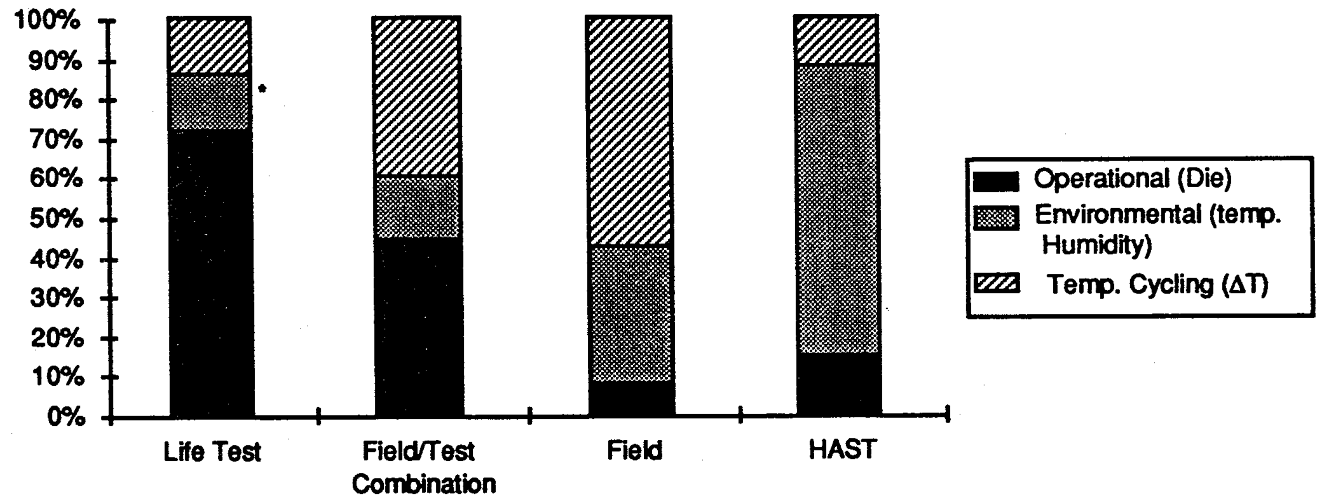
Summary of Failure Category Distributions as a Function of Data/ Test Type



*Environmental and Temperature Cycling failure rates could not be distinguished for Life Test

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Reliability Model

$$\lambda_p = \Pi_{TYPE}[\lambda_{BO}\Pi_T\Pi_{DC}\Pi_{LT} + \lambda_{BE}\Pi_{RHT}\Pi_{HAST} + \lambda_{BTC}\Pi_{TC}\Pi_{TCT}]\Pi_G$$

Where

Π_{TYPE} = Function of Device Type

λ_{BO} = Base operating Die Failure Rate

Π_T = Temperature Factor

Π_{DC} = Function of Duty Cycle

Π_{LT} = Tailoring factor as a function of Life Test Data

λ_{BE} = Base Environmental Failure Rate

Π_{RHT} = Acceleration factor as a function of Temperature, Relative Humidity

Π_{HAST} = Tailoring factor as a function of HAST Test Data

λ_{BTC} = Base Temperature Cycling Failure Rate

Π_{TC} = Acceleration factor as a function of temperature extremes

Π_{TCT} = Tailoring factor as a function of temperature cycling test data

Π_G = Reliability growth factor as a function of year of manufacturer

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Calculation of Π_{TYPE}

	A_I	G_M	G_B	Π_{TYPE} (Geometric Mean)
Digital	1	1	1	1.0
Linear	5.4	2.91	3.09	3.65
Microprocessor Memory	14.0	1.18	2.37	3.40

Failure Categories and Test Data Used to Tailor Model

Failure Rate Term	Failure site/stresses	Test Type
Operational	Die, Operating Temperature	High Temp Operating Life
Environmental	Relative Humidity, Temperature	HAST, 85/85
Temperature Cycling	Change in Temperature	Temperature Cycling

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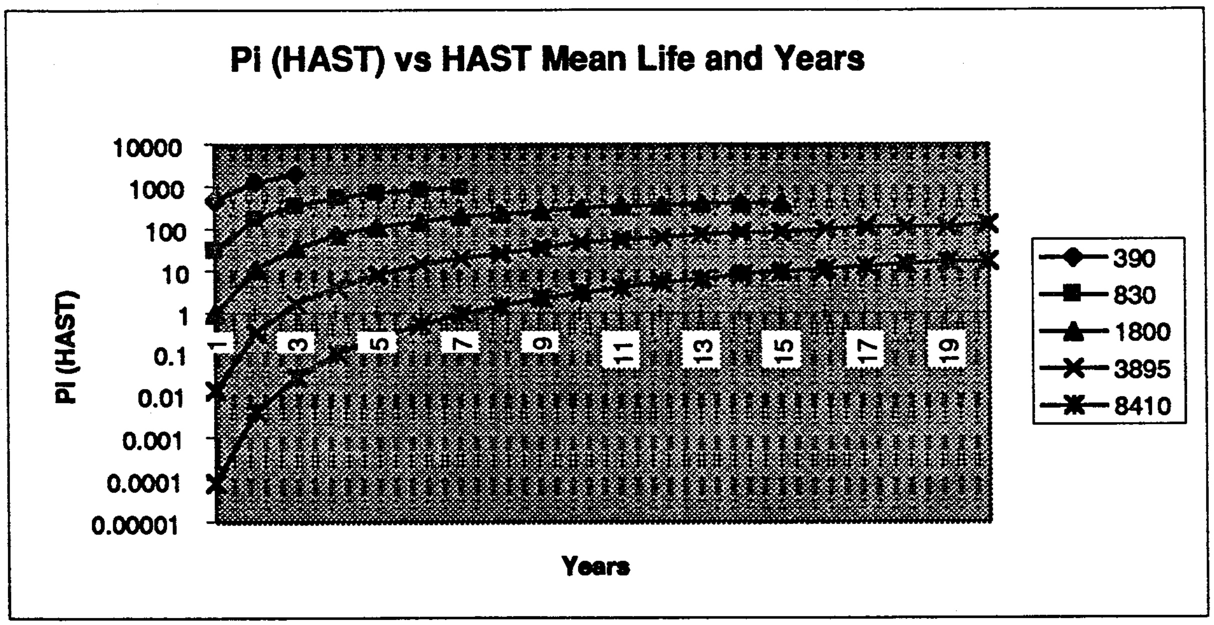
Pi (HAST) vs HAST Mean Life and Years



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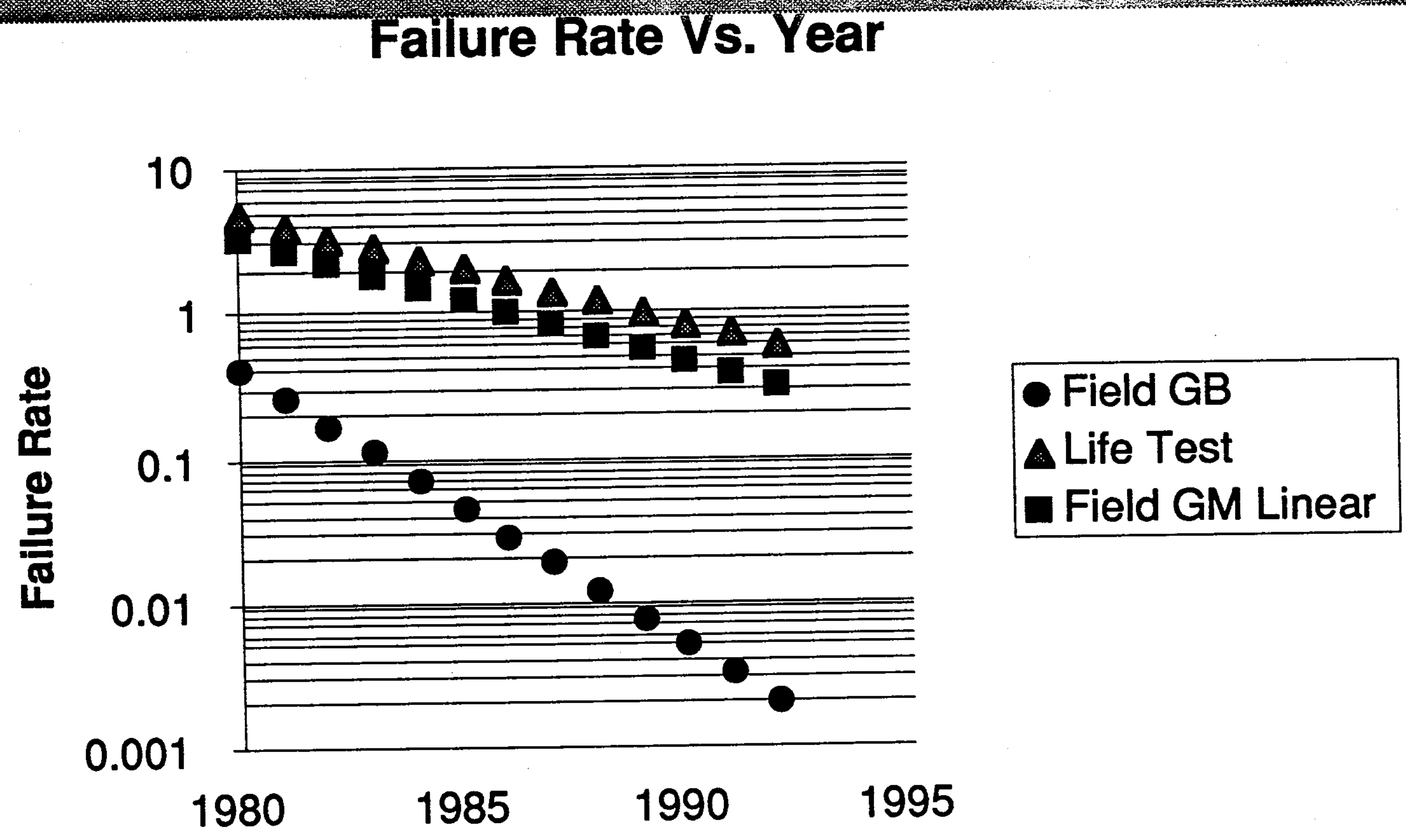
Failure Rate Vs. Year for Field and Life Test Data



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Questions

- How will the prediction results compare to HAST test results?
- How do the prediction results using this model compare with prediction performed using MIL-HDBK-217?
- Over what time period is the growth factor applicable?
- What is the meaning and relevance of the reliability growth factor?
- Why isn't device complexity accounted for?
- Why is the failure rate unit failures per million calendar hours?
- HAST data taken above 130°C is known to result in failure mechanisms that are not typically experienced in the field. Why was data above this value used in development of the model?
- What were the dates of the HAST test results to which the model is normalized?

Stresses Used for Sample Calculations

Stress	Symbol	Severe Condition Value	Benign Condition Value
Ambient Operating Temp	T_{AO}	80°C	30°C
Temperature Rise	T_R	50°C	5°C
Duty Cycle	DC	5%	30%
Ambient Environmental Temp	T_{AE}	70°C	15°C
Relative Humidity	RH	90%	10%
Cycling Rate (Cycles 10^6 hours)	CR	500,000	50,000

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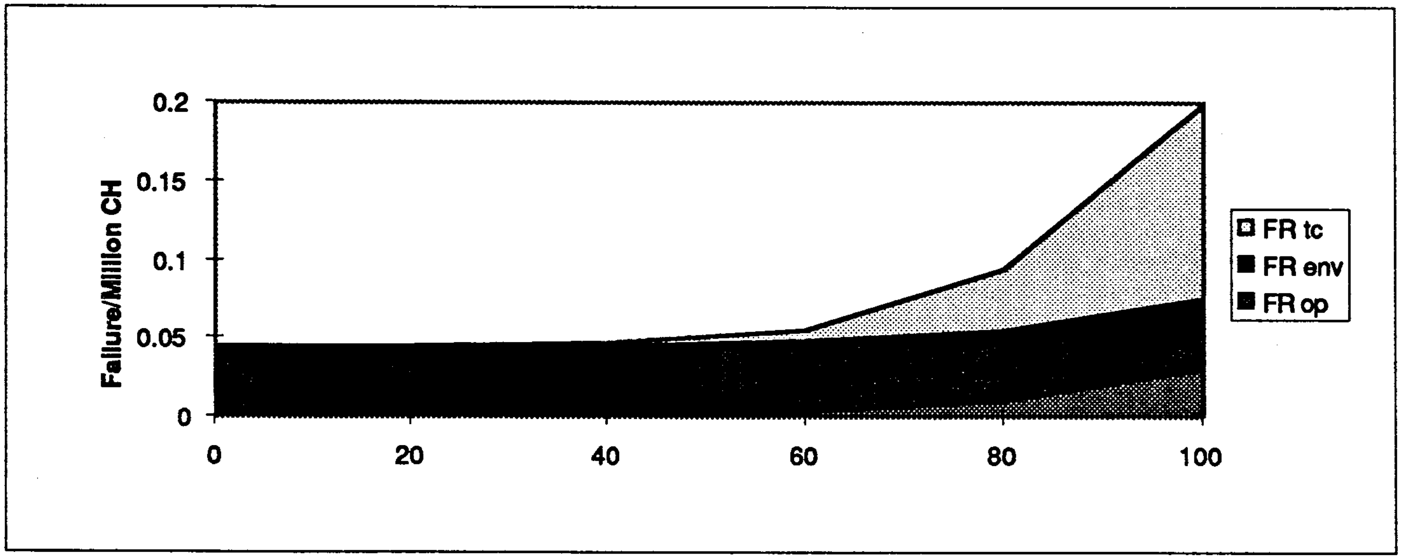
Failure Rate vs Ambient Operating Temperature For Severe Stresses



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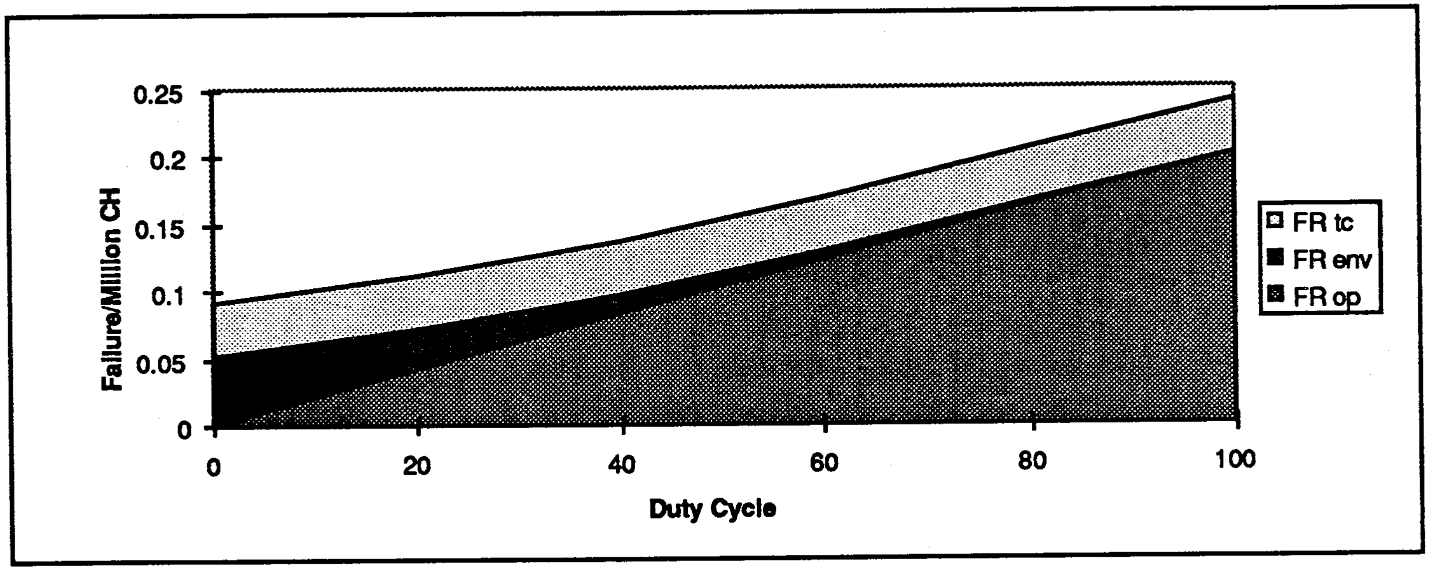
Failure Rate vs Duty Cycle for Severe Stress



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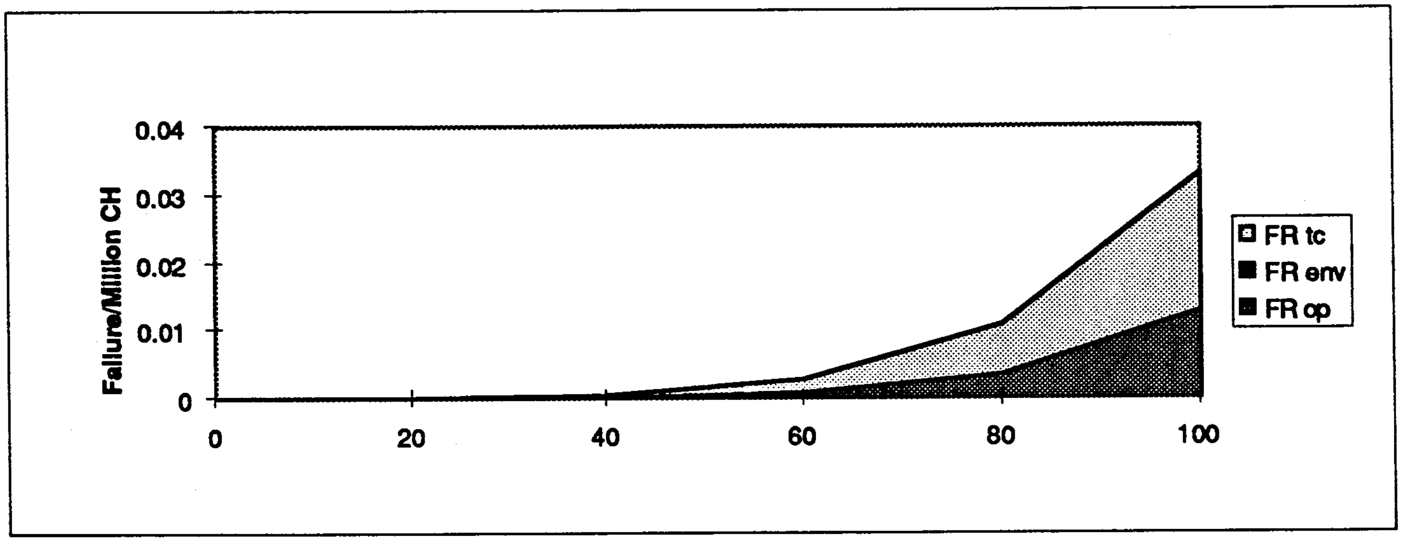
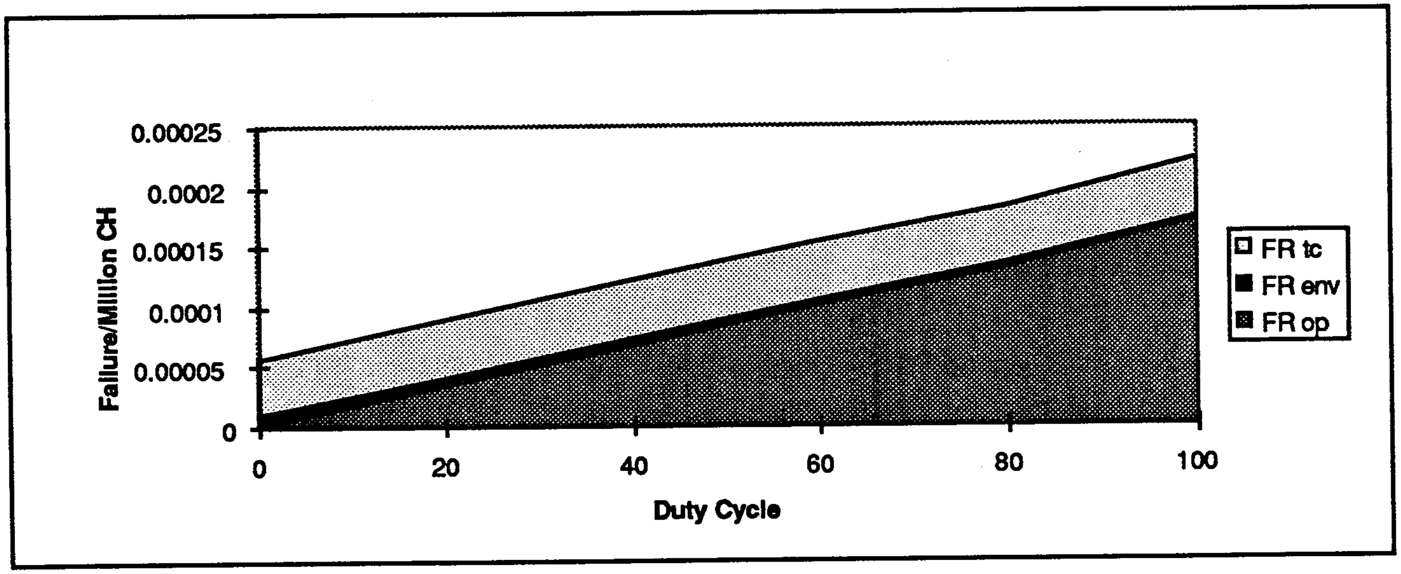
Failure Rate vs Ambient Operating Temperature for Benign Stresses



Failure Rate vs Duty Cycle for Benign Stresses



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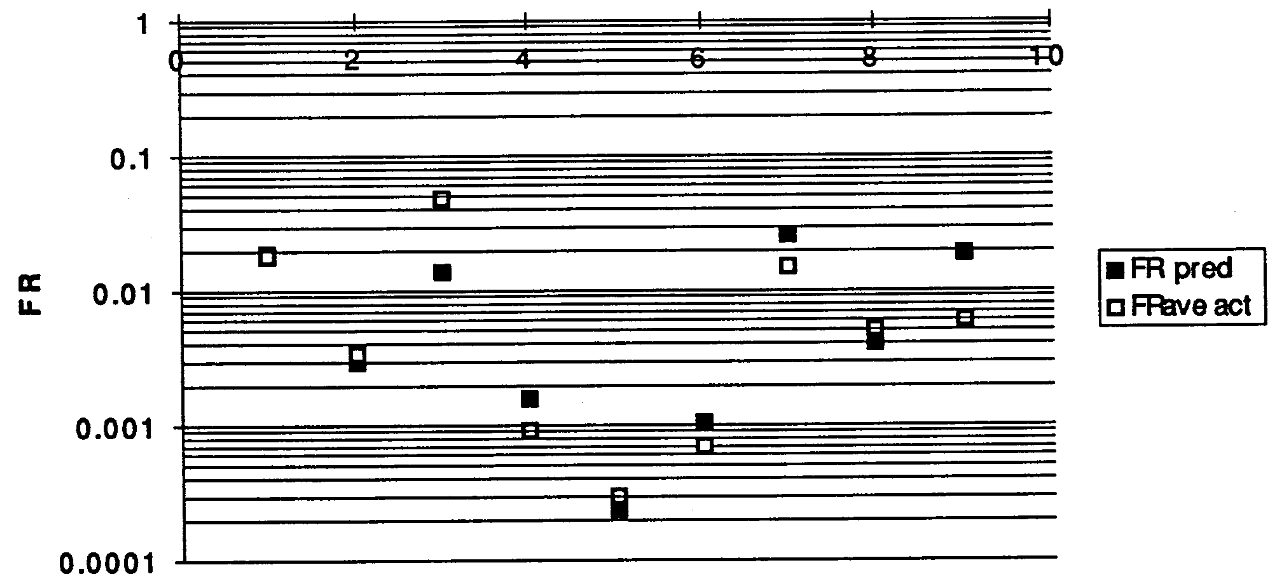
Predicted vs. Observed Failure Rate



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Features of the Model Include:

- Provisions to tailor the prediction if HAST, Life Test, or Temperature cycling data is available.
- A factor which accounts for the growth in reliability that PEMs have experienced.
- Separate failure rates attributable to operational, environmental and temperature cycling stresses so the user can see the stresses that are driving the failure rate.
- The use of industry accepted acceleration factors with constants derived from the empirical data.
- Provisions to estimate the average long term reliability by estimating the failure rate due to known failure mechanisms.
- Inclusion of operating, environmental and temperature cycling related failure rates, yielding the predicted failure rate in failures per million calendar hour which accounts for operating and nonoperating periods.
- Methodology adopted by the Society of Automotive Engineers, various commercial organizations

Conclusions

- PEMs potentially highly reliable in benign applications
- Wide variations in reliability
- Much improved in last 15 years
- Standards becoming prevalent
- Reliability highly dependent on stress
- Each application must be evaluated

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PEM Failure Rate Model Summary

If none of the tailoring factors are used, the fundamental parameters necessary to estimate the reliability of a PEM are:

Device Type - Categorization of the device type into either the linear, digital SSI/MSI, or memory/microprocessor categories.

Ambient Operating Temperature (T_{AO}) - The average ambient temperature within the vicinity of the PEM while the system is in operation.

Ambient Environmental Temperature (T_{AE}) - The ambient temperature within the vicinity of the PEM while the system is non-operating.

Temperature Rise ($T_R = \theta_{JA} P$) - The temperature rise associated with power dissipation. Equal to the thermal resistance (θ_{JA}) times power (P).

Duty Cycle (DC) - The percentage of calendar time that the system is in operation, expressed in decimal form.

Relative Humidity (RH) - The average ambient relative humidity to the PEM expressed in decimal form.

Cycling Rate (CR) - The rate (in cycles per million calendar hours) at which the power is cycled, equivalent to the number of on-off cycles in 10^6 hours.

PEM Failure Rate Model

$$\lambda_P = \Pi_{TYPE}\left[\lambda_{BO}\Pi_T\Pi_{DC}\Pi_{LT} + \lambda_{BE}\Pi_{RHT}\Pi_{HAST} + \lambda_{BTC}\Pi_{TC}\Pi_{CR}\Pi_{TCT}\right]\Pi_G$$

where,

λ_p = Predicted failure rate in failures per million calendar hours

Π_{TYPE} = Device Type Factor
= 1.0 for Digital Devices (SSI/MSI)
= 3.65 for Linear Devices
= 3.40 for Memory and Microprocessors

λ_{BO} = Base Operating Die Failure Rate
= 3.05×10^{-6} Failures/10^6 calendar hours (F/10^6CH)

Π_T = Operating Temperature Factor

$$= \exp\left[-\frac{.8}{8.617 \times 10^{-5}}\left(\frac{1}{T_J} - \frac{1}{298}\right)\right]$$

where,

T_J = Junction Operating Temperature in °K (°C + 273)
= $T_{AO} + T_R$

where,

$T_R = Q_{JA}P$
$= T_{AO} + \theta_{JA}P$
T_{AO} = Ambient Operating Temperature
θ_{JA} = Junction - Ambient Thermal Resistance
P = Power

$$\Pi_{DC} = \frac{DC}{.17}$$

$$DC = \text{Duty Cycle} = \frac{\text{Operating Time}}{\text{Calendar Time}}$$

Π_{LT} = Tailoring Factor as a function of high temperature operating life test on the specific part being predicted

= 1 if no life test data is available

$$= \left(\frac{\lambda_{life}}{.608}\right) \bullet \left(\frac{13335}{\Pi_{T(life)}}\right) \text{ if data is available}$$

λ_{life} = Observed life test operational failure rate(in f/10^6 op-hours)

$$= \frac{\text{Total Number of Failures}}{\text{Cumulative Number of Part Hours}}\left(x10^6\right)$$

$\Pi_{T(life)}$ = Operating Temperature Factor (Π_T) for life test conditions

λ_{BE} = Base Environmental Failure Rate (F/10^6CH)
= .00046 F/10^6CH

Π_{RHT} = Acceleration Factor as a function of Environmental Effective Relative Humidity (RH_{eff}) and Temperature

$$= \exp\left[\frac{-.34}{8.617 \times 10^{-5}}\left(\frac{1}{T_{AE}} - \frac{1}{298}\right)\right]\left(\frac{RH_{eff}}{.5}\right)^3$$

T_{AE} = Environment Ambient Temperature (in °K)
RH_{eff} = Effective Relative Humidity

$$= (DC)(RH)\exp\left[5230\left(\frac{1}{T_J} - \frac{1}{T_{AE}}\right)\right] + (1 - DC)(RH)$$

RH = Ambient Average Relative Humidity

Π_{HAST} = Tailoring Factor as a Function of HAST Data on the Specific Part Being Predicted

= 1 if no HAST data is available

Table 6.8-1 contains the Π_{HAST} values as a function of the predicted mean time to failure and the time period (in years) over which the average failure rate is to be predicted. The Mean Time To Failure (μ) is:

$$\mu = \mu_{HAST}\frac{\Pi_{RHT(HAST)}}{1.29}$$

μ_{HAST} = The observed MTTF from HAST Testing from the lognormal Distribution

$\Pi_{RHT(HAST)}$ = Acceleration Factor under the HAST Test Conditions

λ_{BTC} = Base Temperature Cycling Failure Rate
= .00099 F/10^6CH

Π_{TC} = Acceleration Factor as a Function of Temperature Extremes

$$= \left(\frac{\Delta T}{46.1}\right)^4$$

where,

$\Delta T = T_{AO} + T_R - T_{AE}$ (°C)

T_{AO} = Operating Ambient Temperature (°C)
T_R = Temperature Rise
$= \theta_{JC}P$
T_{AE} = Ambient Environmental Temperature during Non-operation

Π_{CR} = Cycling Rate Factor

$$= \frac{CR}{123138}$$

where,

CR = Number of Expected Temperature Cycles of Magnitude ΔT per 10^6 calendar hours.

Π_{TCT} = Tailoring Factor as a function of Temperature Cycling Tests.

= 1, if no temperature cycling data is available

$$= \frac{1}{.43}(\%\ \text{Fail} / 1000\ \text{cycles})\left(\frac{215}{\Delta T_T}\right)^4 \text{, if temperature cycling data is available}$$

where,

% Fail/1000 Cycles = population percentage failing at 1000 temperature cycles (i.e., Failures/Population x 100)

ΔT_T = Change in Temperature during Temperature Cycling Tests

Π_G = Growth Factor as a Function of Year of Manufacture

= 1, if any empirical data was used to tailor the prediction using Π_{LT}, Π_{HAST}, or Π_{TCT}

= $\exp[-B(t-1992)]$

B = .293 For linear devices
= .473 For Digital SS1/MS1
= .479 For memory/microprocessors

Π_{HAST} VS. HAST MEAN LIFE AND TIME

	Years																			
μ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
25100	3.1E+3																			
27108	2.7E+3																			
29276.64	2.3E+3																			
31618.771	1.9E+3																			
34148.273	1.6E+3	3.2E+3																		
36880.135	1.3E+3	2.8E+3																		
39830.546	1.1E+3	2.5E+3																		
43016.989	8.7E+2	2.1E+3																		
46458.348	7.1E+2	1.8E+3																		
50175.016	5.7E+2	1.6E+3																		
54189.017	4.5E+2	1.3E+3	1.9E+3																	
58524.139	3.6E+2	1.1E+3	1.7E+3																	
63206.07	2.8E+2	9.5E+2	1.5E+3																	
68262.556	2.2E+2	7.9E+2	1.3E+3	1.6E+3																
73723.56	1.7E+2	6.5E+2	1.1E+3	1.4E+3																
79621.445	1.3E+2	5.4E+2	9.3E+2	1.2E+3																
85991.16	9.9E+1	4.4E+2	7.9E+2	1.1E+3	1.3E+3															
92870.453	7.5E+1	3.5E+2	6.6E+2	9.2E+2	1.1E+3															
100300.09	5.6E+1	2.8E+2	5.5E+2	7.9E+2	9.7E+2	1.1E+3														
108324.1	4.2E+1	2.3E+2	4.6E+2	6.7E+2	8.4E+2	9.7E+2														
116990.02	3.1E+1	1.8E+2	3.8E+2	5.7E+2	7.2E+2	8.5E+2	9.4E+2													
126349.23	2.3E+1	1.4E+2	3.1E+2	4.8E+2	6.2E+2	7.4E+2	8.3E+2													
136457.16	1.6E+1	1.1E+2	2.5E+2	4.0E+2	5.3E+2	6.4E+2	7.3E+2	8.0E+2												
147373.74	1.2E+1	8.5E+1	2.0E+2	3.3E+2	4.4E+2	5.5E+2	6.3E+2	7.0E+2												
159163.64	8.5E+0	6.5E+1	1.6E+2	2.7E+2	3.7E+2	4.7E+2	5.5E+2	6.2E+2	6.7E+2											
171896.73	6.0E+0	5.0E+1	1.3E+2	2.2E+2	3.1E+2	4.0E+2	4.7E+2	5.3E+2	5.9E+2	6.2E+2										
185648.47	4.3E+0	3.8E+1	1.0E+2	1.8E+2	2.6E+2	3.3E+2	4.0E+2	4.6E+2	5.1E+2	5.5E+2										
200500.34	3.0E+0	2.8E+1	7.8E+1	1.4E+2	2.1E+2	2.8E+2	3.4E+2	3.9E+2	4.4E+2	4.8E+2	5.2E+2									
216540.37	2.1E+0	2.1E+1	6.1E+1	1.1E+2	1.7E+2	2.3E+2	2.8E+2	3.4E+2	3.8E+2	4.2E+2	4.5E+2	4.9E+2								
233863.6	1.4E+0	1.5E+1	4.7E+1	9.0E+1	1.4E+2	1.9E+2	2.4E+2	2.8E+2	3.3E+2	3.6E+2	3.9E+2	4.3E+2	4.5E+2							
252572.69	9.7E-1	1.1E+1	3.6E+1	7.1E+1	1.1E+2	1.5E+2	2.0E+2	2.4E+2	2.8E+2	3.1E+2	3.4E+2	3.7E+2	3.9E+2	4.2E+2	4.3E+2					
272778.5	6.6E-1	8.3E+0	2.7E+1	5.5E+1	8.9E+1	1.3E+2	1.6E+2	2.0E+2	2.3E+2	2.6E+2	2.9E+2	3.2E+2	3.4E+2	3.6E+2	3.8E+2	4.0E+2				
294600.78	4.4E-1	6.0E+0	2.0E+1	4.3E+1	7.0E+1	1.0E+2	1.3E+2	1.6E+2	1.9E+2	2.2E+2	2.5E+2	2.7E+2	3.0E+2	3.2E+2	3.4E+2	3.5E+2	3.7E+2			
318168.85	2.9E-1	4.3E+0	1.5E+1	3.3E+1	5.5E+1	8.1E+1	1.1E+2	1.3E+2	1.6E+2	1.8E+2	2.1E+2	2.3E+2	2.5E+2	2.7E+2	2.9E+2	3.1E+2	3.2E+2	3.4E+2		
343622.35	1.9E-1	3.0E+0	1.1E+1	2.5E+1	4.3E+1	6.4E+1	8.6E+1	1.1E+2	1.3E+2	1.5E+2	1.8E+2	2.0E+2	2.2E+2	2.4E+2	2.5E+2	2.7E+2	2.8E+2	2.9E+2	3.1E+2	3.2E+2
371112.14	1.3E-1	2.1E+0	8.2E+0	1.9E+1	3.3E+1	5.0E+1	6.9E+1	8.9E+1	1.1E+2	1.3E+2	1.5E+2	1.7E+2	1.8E+2	2.0E+2	2.2E+2	2.3E+2	2.4E+2	2.6E+2	2.7E+2	2.8E+2
400801.11	8.3E-2	1.5E+0	6.0E+0	1.4E+1	2.5E+1	3.9E+1	5.5E+1	7.1E+1	8.8E+1	1.0E+2	1.2E+2	1.4E+2	1.5E+2	1.7E+2	1.8E+2	2.0E+2	2.1E+2	2.2E+2	2.3E+2	2.4E+2
432865.2	5.3E-2	1.0E+0	4.3E+0	1.1E+1	1.9E+1	3.0E+1	4.3E+1	5.7E+1	7.1E+1	8.5E+1	1.0E+2	1.2E+2	1.3E+2	1.4E+2	1.6E+2	1.7E+2	1.8E+2	1.9E+2	2.0E+2	2.1E+2
467494.42	3.4E-2	7.1E-1	3.1E+0	7.8E+0	1.5E+1	2.3E+1	3.4E+1	4.5E+1	5.7E+1	6.9E+1	8.2E+1	9.5E+1	1.1E+2	1.2E+2	1.3E+2	1.4E+2	1.5E+2	1.6E+2	1.7E+2	1.8E+2
504893.97	2.2E-2	4.9E-1	2.2E+0	5.7E+0	1.1E+1	1.8E+1	2.6E+1	3.5E+1	4.5E+1	5.5E+1	6.6E+1	7.7E+1	8.8E+1	9.9E+1	1.1E+2	1.2E+2	1.3E+2	1.4E+2	1.5E+2	1.6E+2
545285.49	1.4E-2	3.3E-1	1.6E+0	4.1E+0	8.1E+0	1.4E+1	2.0E+1	2.8E+1	3.6E+1	4.4E+1	5.3E+1	6.3E+1	7.2E+1	8.1E+1	9.0E+1	9.9E+1	1.1E+2	1.2E+2	1.2E+2	1.3E+2
588908.33	8.6E-3	2.2E-1	1.1E+0	3.0E+0	6.0E+0	1.0E+1	1.5E+1	2.1E+1	2.8E+1	3.5E+1	4.3E+1	5.0E+1	5.8E+1	6.6E+1	7.4E+1	8.2E+1	9.0E+1	9.7E+1	1.0E+2	1.1E+2
636021	5.3E-3	1.5E-1	7.6E-1	2.1E+0	4.4E+0	7.6E+0	1.2E+1	1.6E+1	2.2E+1	2.7E+1	3.4E+1	4.0E+1	4.7E+1	5.4E+1	6.1E+1	6.7E+1	7.4E+1	8.1E+1	8.7E+1	9.4E+1
686902.67	3.3E-3	9.7E-2	5.2E-1	1.5E+0	3.2E+0	5.6E+0	8.7E+0	1.2E+1	1.7E+1	2.1E+1	2.6E+1	3.2E+1	3.8E+1	4.3E+1	4.9E+1	5.5E+1	6.1E+1	6.7E+1	7.2E+1	7.8E+1
741854.89	2.0E-3	6.4E-2	3.6E-1	1.1E+0	2.3E+0	4.1E+0	6.5E+0	9.4E+0	1.3E+1	1.6E+1	2.1E+1	2.5E+1	3.0E+1	3.5E+1	3.9E+1	4.4E+1	5.0E+1	5.5E+1	5.9E+1	6.4E+1
801203.28	1.2E-3	4.2E-2	2.4E-1	7.5E-1	1.6E+0	3.0E+0	4.8E+0	7.1E+0	9.7E+0	1.3E+1	1.6E+1	2.0E+1	2.3E+1	2.7E+1	3.2E+1	3.6E+1	4.0E+1	4.4E+1	4.9E+1	5.3E+1
865299.54	7.2E-4	2.7E-2	1.6E-1	5.2E-1	1.2E+0	2.2E+0	3.5E+0	5.3E+0	7.3E+0	9.6E+0	1.2E+1	1.5E+1	1.8E+1	2.2E+1	2.5E+1	2.8E+1	3.2E+1	3.6E+1	3.9E+1	4.3E+1
934523.51	4.3E-4	1.7E-2	1.1E-1	3.6E-1	8.2E-1	1.6E+0	2.6E+0	3.9E+0	5.5E+0	7.2E+0	9.4E+0	1.2E+1	1.4E+1	1.7E+1	2.0E+1	2.3E+1	2.6E+1	2.9E+1	3.2E+1	3.5E+1
1009285.4	2.5E-4	1.1E-2	7.3E-2	2.4E-1	5.7E-1	1.1E+0	1.9E+0	2.8E+0	4.1E+0	5.4E+0	7.1E+0	8.9E+0	1.1E+1	1.3E+1	1.5E+1	1.8E+1	2.0E+1	2.3E+1	2.5E+1	2.8E+1
1090028.2	1.5E-4	6.9E-3	4.8E-2	1.6E-1	4.0E-1	7.8E-1	1.3E+0	2.1E+0	3.0E+0	4.0E+0	5.3E+0	6.8E+0	8.3E+0	1.0E+1	1.2E+1	1.4E+1	1.6E+1	1.8E+1	2.0E+1	2.2E+1
1177230.5	8.6E-5	4.3E-3	3.1E-2	1.1E-1	2.7E-1	5.5E-1	9.5E-1	1.5E+0	2.2E+0	3.0E+0	4.0E+0	5.1E+0	6.3E+0	7.7E+0	9.1E+0	1.1E+1	1.2E+1	1.4E+1	1.6E+1	1.8E+1
1271408.9	5.0E-5	2.7E-3	2.0E-2	7.4E-2	1.9E-1	3.8E-1	6.7E-1	1.1E+0	1.6E+0	2.2E+0	2.9E+0	3.8E+0	4.8E+0	5.8E+0	7.0E+0	8.2E+0	9.5E+0	1.1E+1	1.2E+1	1.4E+1
1373121.6	2.8E-5	1.6E-3	1.3E-2	4.9E-2	1.3E-1	2.6E-1	4.7E-1	7.6E-1	1.1E+0	1.6E+0	2.2E+0	2.8E+0	3.5E+0	4.4E+0	5.3E+0	6.2E+0	7.3E+0	8.4E+0	9.5E+0	1.1E+1
1482971.4	1.6E-5	1.0E-3	8.2E-3	3.2E-2	8.5E-2	1.8E-1	3.3E-1	5.4E-1	8.1E-1	1.1E+0	1.6E+0	2.1E+0	2.6E+0	3.3E+0	4.0E+0	4.7E+0	5.5E+0	6.4E+0	7.3E+0	8.3E+0
1601609.1	9.1E-6	6.0E-4	5.2E-3	2.1E-2	5.6E-2	1.2E-1	2.3E-1	3.7E-1	5.7E-1	8.2E-1	1.1E+0	1.5E+0	1.9E+0	2.4E+0	2.9E+0	3.5E+0	4.2E+0	4.9E+0	5.6E+0	6.4E+0
1729737.8	5.1E-6	3.6E-4	3.2E-3	1.3E-2	3.7E-2	8.2E-2	1.5E-1	2.6E-1	4.0E-1	5.8E-1	8.1E-1	1.1E+0	1.4E+0	1.8E+0	2.2E+0	2.6E+0	3.1E+0	3.7E+0	4.2E+0	4.9E+0
1868116.8	2.8E-6	2.2E-4	2.0E-3	8.6E-3	2.4E-2	5.5E-2	1.0E-1	1.8E-1	2.8E-1	4.1E-1	5.8E-1	7.8E-1	1.0E+0	1.3E+0	1.6E+0	1.9E+0	2.3E+0	2.7E+0	3.2E+0	3.7E+0
2017566.2	1.5E-6	1.3E-4	1.2E-3	5.5E-3	1.6E-2	3.6E-2	7.0E-2	1.2E-1	1.9E-1	2.8E-1	4.1E-1	5.6E-1	7.3E-1	9.3E-1	1.2E+0	1.4E+0	1.7E+0	2.0E+0	2.4E+0	2.8E+0
2178971.4	8.4E-7	7.5E-5	7.6E-4	3.4E-3	1.0E-2	2.4E-2	4.7E-2	8.3E-2	1.3E-1	2.0E-1	2.9E-1	3.9E-1	5.2E-1	6.7E-1	8.4E-1	1.0E+0	1.3E+0	1.5E+0	1.8E+0	2.0E+0
2353289.2	4.5E-7	4.3E-5	4.6E-4	2.2E-3	6.6E-3	1.6E-2	3.1E-2	5.6E-2	9.0E-2	1.4E-1	2.0E-1	2.8E-1	3.7E-1	4.8E-1	6.0E-1	7.5E-1	9.1E-1	1.1E+0	1.3E+0	1.5E+0
2541552.3	2.4E-7	2.5E-5	2.8E-4	1.3E-3	4.2E-3	1.0E-2	2.0E-2	3.7E-2	6.1E-2	9.3E-2	1.4E-1	1.9E-1	2.6E-1	3.4E-1	4.3E-1	5.4E-1	6.6E-1	7.9E-1	9.4E-1	1.1E+0

Prediction Example

As an example of using the PEM model, consider the following conditions:

Device Type = Microprocessor

Ambient Operating Temperature(T_{AO}) = 40°C

Temperature Rise (T_R) = 20°C

Duty Cycle (DC) = 30%

Ambient Environmental Temp (T_{AE}) = 25°C

Relative Humidity = 60%

Cycling Rate (CR) = 175,000 cycles/10^6 calendar hours

Year = 1992

$$\lambda_P = \Pi_{TYPE}\left[\lambda_{BO}\Pi_T\left(\frac{\Pi_{DC}}{.17}\right)\Pi_{LT} + \lambda_{BE}\Pi_{RHT}\Pi_{HAST} + \lambda_{BTC}\Pi_{TC}\Pi_{CR}\Pi_{TCT}\right]\Pi_G$$

Π_{TYPE} = 3.4

λ_{BO} = .00000305

$$\Pi_T = \exp\left(\frac{-.8}{8.617\text{x}10^{-5}}\left(\frac{1}{40+20+273}\right)-\left(\frac{1}{298}\right)\right) = 26.43$$

$$\Pi_{DC} = \frac{DC}{.17} = \frac{.30}{.17} = 1.765$$

Π_{LT} = 1 (No available life test data)

λ_{BE} = .00046

$$\Pi_{RHT} = \exp\left[\frac{-.34}{8.617\text{x}10^{-5}}\left(\frac{1}{25+273}-\frac{1}{298}\right)\right]\left[\frac{RH_{eff}}{.5}\right]^3$$

$$RH_{eff} = (DC)\,(RH)\,\exp\left[5230\left(\frac{1}{T_J}-\frac{1}{T_{AO}}\right)\right] + (1-DC)\,(RH)$$

$$= (.30)\,(.60)\,\exp\left[5230\left(\left(\frac{1}{40+20+273}\right)-\left(\frac{1}{40+273}\right)\right)\right] + (.7)\,(.6) = .486$$

Π_{RHT} = .918

Π_{HAST} = 1 (No HAST data available)

λ_{BTC} = .00099

$$\Pi_{TC} = \left(\frac{\Delta T}{46.1}\right)^4$$

$$\Delta T = T_{AO} + T_R - T_{AE}$$

$$= 40 + 20 - 25$$

$$= 35°\text{C}$$

$$\Pi_{TC} = \left(\frac{35}{46.1}\right)^4 = .332$$

$$\Pi_{CR} = \frac{CR}{123138} = \frac{175{,}000}{123{,}138} = 1.421$$

Π_{TCT} = 1 (No temperature cycling test data available)

$$\Pi_G = \exp[-B(t-1992)]$$

For t = 1992,

$$\Pi_G = \exp[-.479(1992-1992)]$$

$$= 1$$

Therefore, the predicted failure rate is:

$$\lambda_P = 3.4[(.00000305)(26.43)(1.765)(1) + (.00046)(.918)(1) + (.00099)(.332)(1.421)(1)](1)$$

$$= .0035 \text{ Failures}/10^6 \text{ CH}$$

If this failure rate must be added to an operating reliability prediction in the units of failures per million operating hour, the predicted failure rate is;

$$\lambda_P = \frac{.0035 \text{ F}/10^6\text{CH}}{\text{DC}} = .0117 \text{ (Failures}/10^6 \text{ op hrs.)}$$

Long Term Storage of PEM

16 November 1995

Bill Garry
Westinghouse

SHARP

- The Problem
- The Plan
- The Team

SHARP

The Problem

- Need for Lower Cost Systems
- Lack of models for Long Term Storage
- Not Just a Longbow Missile Problem

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Two Potential Solutions

- Long Term Storage - Actual
- Accelerated Testing Without Bias

Objective

- Develop a Model to Relate Accelerated Test Environments to LTDS

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The Plan: Five Tasks

I. LTDS Environmental Study

II. Analytical Model Study

III. Experimental Study

IV. Analysis/Model Reconciliation

V. Final Report

SHARP

Task I: LTDS Environmental Study

A. Define Magnitudes and Durations of Actual LTDS Environments

B. Develop a Coordinated Test Plan to Study Effects of Principal Environments of Concern

- Combined Temperature - Humidity
- Thermal Cycling
- Ionic Contamination

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Strawman Test Regimen - Four HAST Groups

- Group I : 85°C, 85% RH
- Group II : 130°C, 85% RH
- Group III : 130°C, 95% RH
- Group IV : 150°C, 95% RH

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STRAWMAN TEST REGIMEN - SEQUENTIAL TESTS

STEP	STRESS	CONDITIONS
1	T/C	50°C to 125°C, 16 min. dwell, 50 cycles
2	HAST	100 hours per group
3	T/C	-55°C to 125°C, 10 min. dwell, 50 cycles
4	HAST	100 hours per group
5	T/C	75°C to 150°C, 16 min. dwell, 50 cycles
6	HAST	100 hours per group

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STEP	STRESS	CONDITIONS
7	SALT FOG	120 hours
8	T/C	0°C to 75°C, 16 min dwell, 150 cycles
		<clean & dry all part surfaces>
9	HAST	To t_{50} for each group

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Task II: Analytical Model Study

- Review Literature, ID Potential Failure Mechanisms
- Study Extant Models - Strengths, Weaknesses
- Evaluate Compatibility with Geometric and Material Characteristics of PEM for LTDS
- Define Expected Failure Distributions
- Define Expected Acceleration Factors for LTDS

Output: Potential Model Framework

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Task III - Experimental Study

- 5 Test Groups (4 HAST Groups, 1 HSM)
- 2 Sub-groups per Group
    - Minimum Geometry
    - Maximum Geometry
- Record Variables for Each Group
    - Molding Compound
        - Elastic Modulus
        - Thermal Expansion Coefficient
        - Glass Transition Temperature
        - Extractable Ionic Species Level

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<u>Task III</u> - Experimental Study

- Lead Frame
  - Elastic Modulus
  - Thermal Expansion Coefficient
- Package
  - Type & Dimensions
  - Number of Leads
  - Plastic Thickness Above Die
  - Die Size

•Determine Partial Factorial Plan

•Define Group and Subgroup Sample Sizes

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Task III - Continued

- Obtain Test Parts
- Subject All Parts to Preconditioning
  - 5 cycles, -20°C to 50°C, 40 min., 10 min dwell (shipping simulation)
  - 85°C/85% RH, 168 hours (storage simulation)
  - 1 cycle simulated IR reflow/vapor phase time/temperature exposure

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<u>Task III</u> - Continued

- Part Testing - Initial and Periodic
  - External Visual
  - Acoustic Microscopy
  - Electrical Parametric (-40°C, 25°C, 85°C)
  - Remove Failed Parts

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<u>Task III</u> - Continued (Phew!)

- Conduct Tests - per Coordinated Test Plan
- Failure Definition:
  - Catastrophic - short or open
  - Degraded - out of spec condition
- Failure Analysis
  - Site, Mode, Mechanism

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Task IV - Analysis/Model Reconciliation

- Data Recording, Plotting
- For Each Failure Mechanism,
  - Distribution
  - t_{50}, t_{16}
- Fit Validated Data to Models from Task II
- Conduct Sensitivity Analysis

Task V - Final Report

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Schedule

	4Q95	1Q96	2Q96	3Q96	4Q96	1Q97	2Q97	3Q97
Task I	X - - -	- - -	X					
Task II	X - - -	- - -	- - -	X				
Task III			X - - -	- - -	- - -	- - -	X	
Task IV				X - - -	- - -	- - -	- - -	X
Task V								X

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The Team

- Westinghouse Electric Corp., Baltimore
  - Stan Whelan, Bill Garry
- University of Maryland CALCE-EPRC
  - Dr. Pat McCluskey, Dr. Mike Pecht
- Advisors, USA MICOM
  - Dave Locker, Dr. Noel Donlin
- Other Interested Parties
  - Buff Slay, Texas Instruments, Dallas, TX
  - Jim Reilly, Rome Labs, Rome, NY
  - Ron DiCristoforo, Lockheed - Martin, Orlando

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An Appeal

- Suggestions, Critique Welcome
- Participation On Technical Advisory Panel (TAP)
  - Parts
  - Ideas

ACCELERATED TESTING
FOR TELECOMMUNICATIONS EQUIPMENT

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Introduction.

Rapid technology changes, diverse global environments, short product cycles and higher customer expectations at lower cost.

Infant mortality.

Need for comprehensive quality programs.

Product Weaknesses and Stress Testing.

Screening versus corrective actions.
Stress-strength contours.
How is system stress testing relate to component quality?
How does stress testing improve product quality at low cost?

AT&T

PRODUCT RELIABILITY AND ENVIRONMENTAL STRESS TESTING

Introduction

Conventional Reliability Concepts.

Design for reliability

Product Weaknesses and Stress Testing.

Systematic Formulation

EST Programs

Stress stimuli

Reliability Programs

Fix the problems in response to

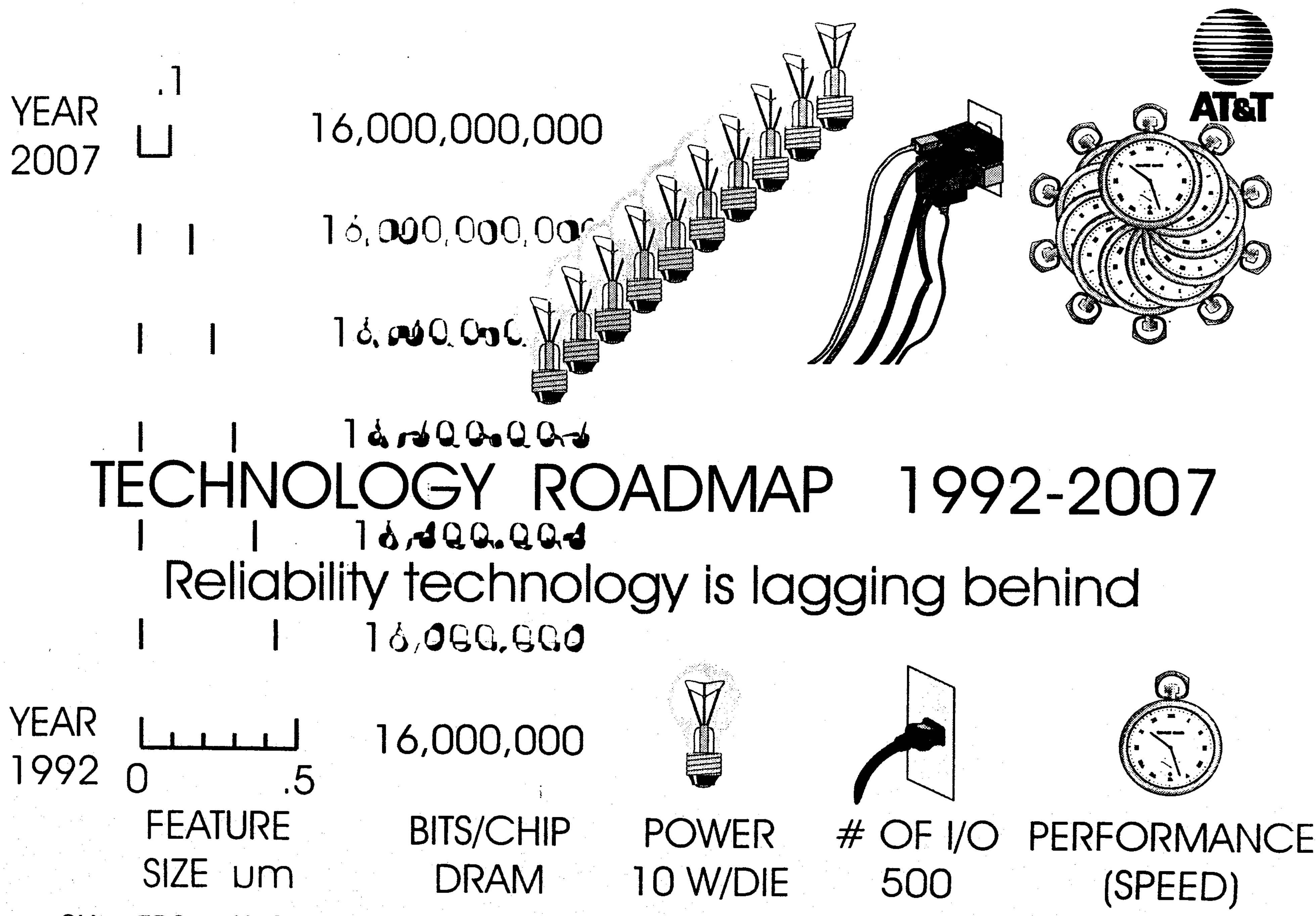
- ☞ field returns.
- ☞ factory test data.

New product planning

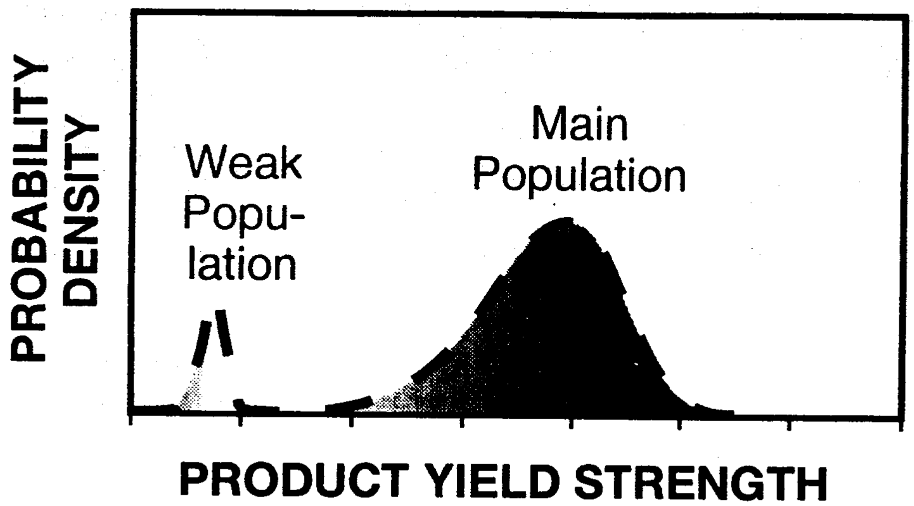
- ☞ meet reliability qualification.
- ☞ predict failure rate.
- ☞ margins in design, component performance and process.
- ☞ design verification test.

Stress Testing

- ☞ ESS.
- ☞ EST.



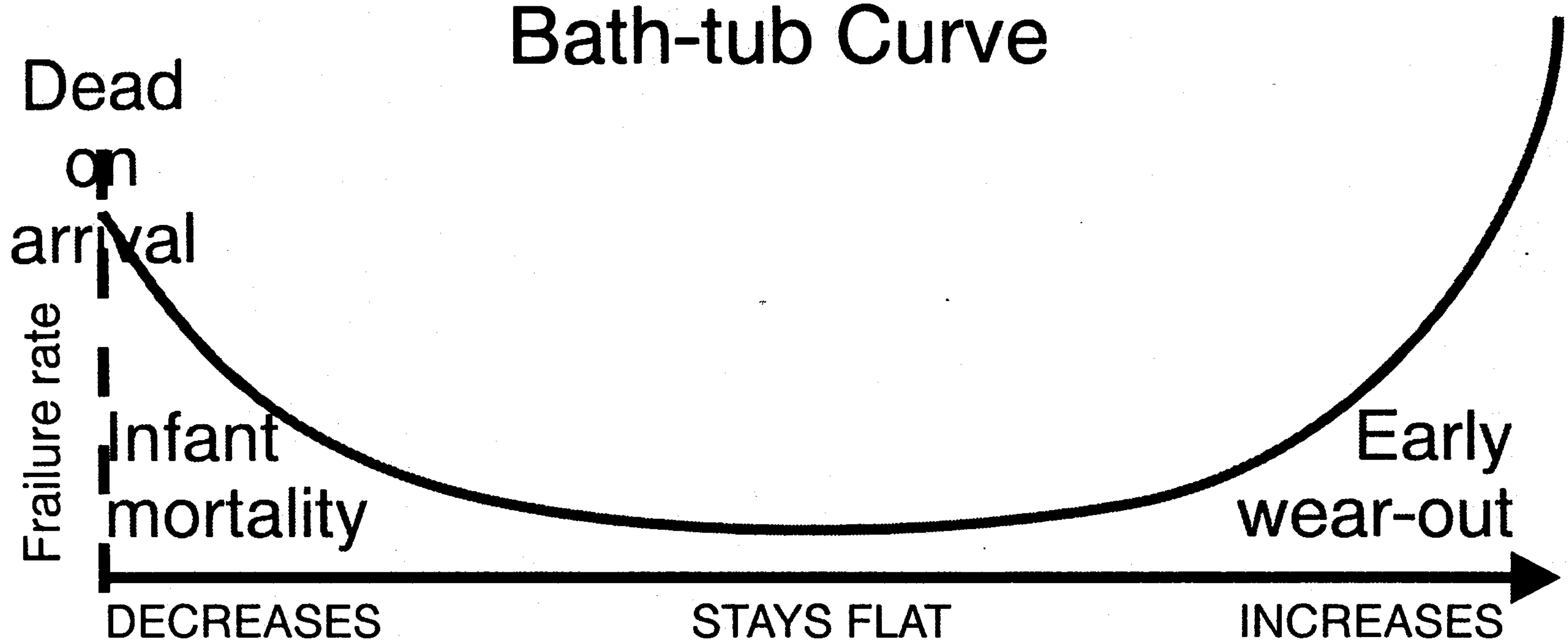
GM. ERC AN CH9507.



Predict failure rate?

Many failure modes are still empirical.
Too few data for new products.

Bath-tub Curve



Typical failure rate of a product

decreases during infant mortality,
increases during wear-out,
stays roughly constant in between.

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Challenges

TECHNOLOGY GROWTH 1

Relibility programs cannot catch up.

HUMAN LIFE 2

Failures upsets customers more.

DIVERSE CUSTOMERS 3

Product sees more failure conditions.

SHORT PRODUCT CYCLE 4

Cannot improve design.

COMPETITIVE MARKET 5

Expect better quality at lower cost.

CHALLENGES

a reliability program
a pro-active reliability program
a low COGS and fast Time-to-Market program

separate reliability expertise
integrated team

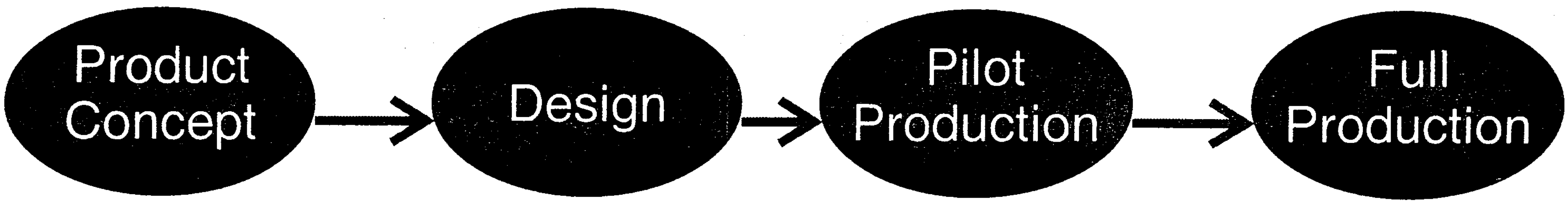
empirical
systematic

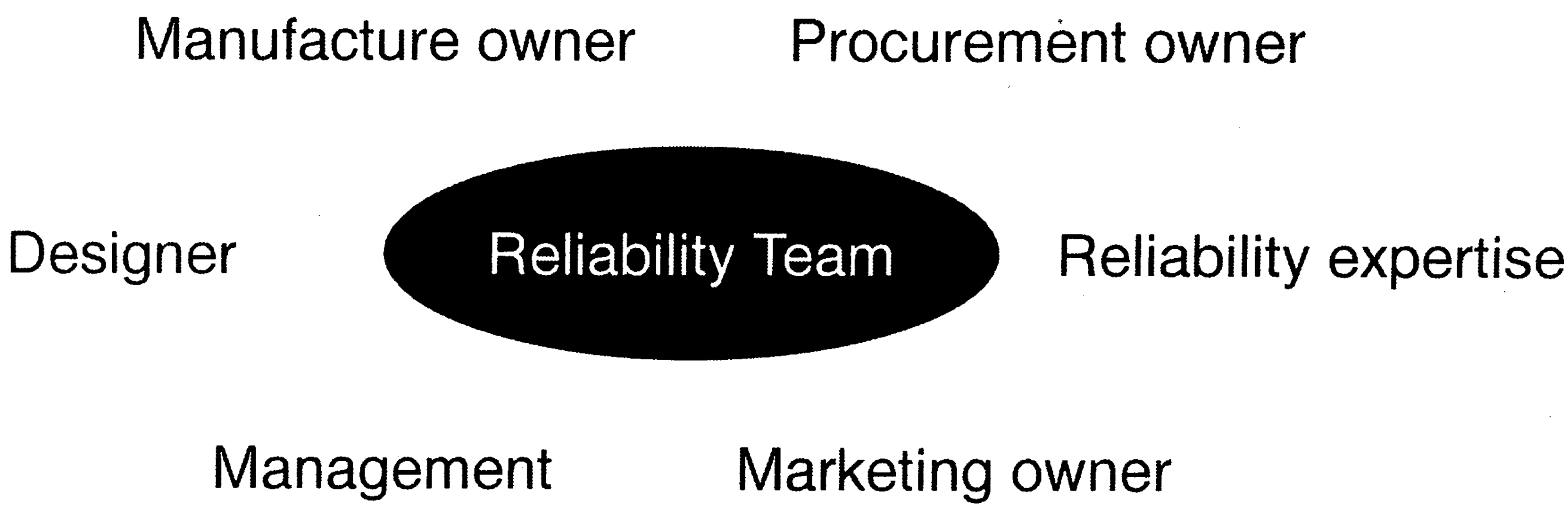
long term reliability
infant mortality

"... like rowing against the stream."

higher end systems
consumer products

Reliability Strategy





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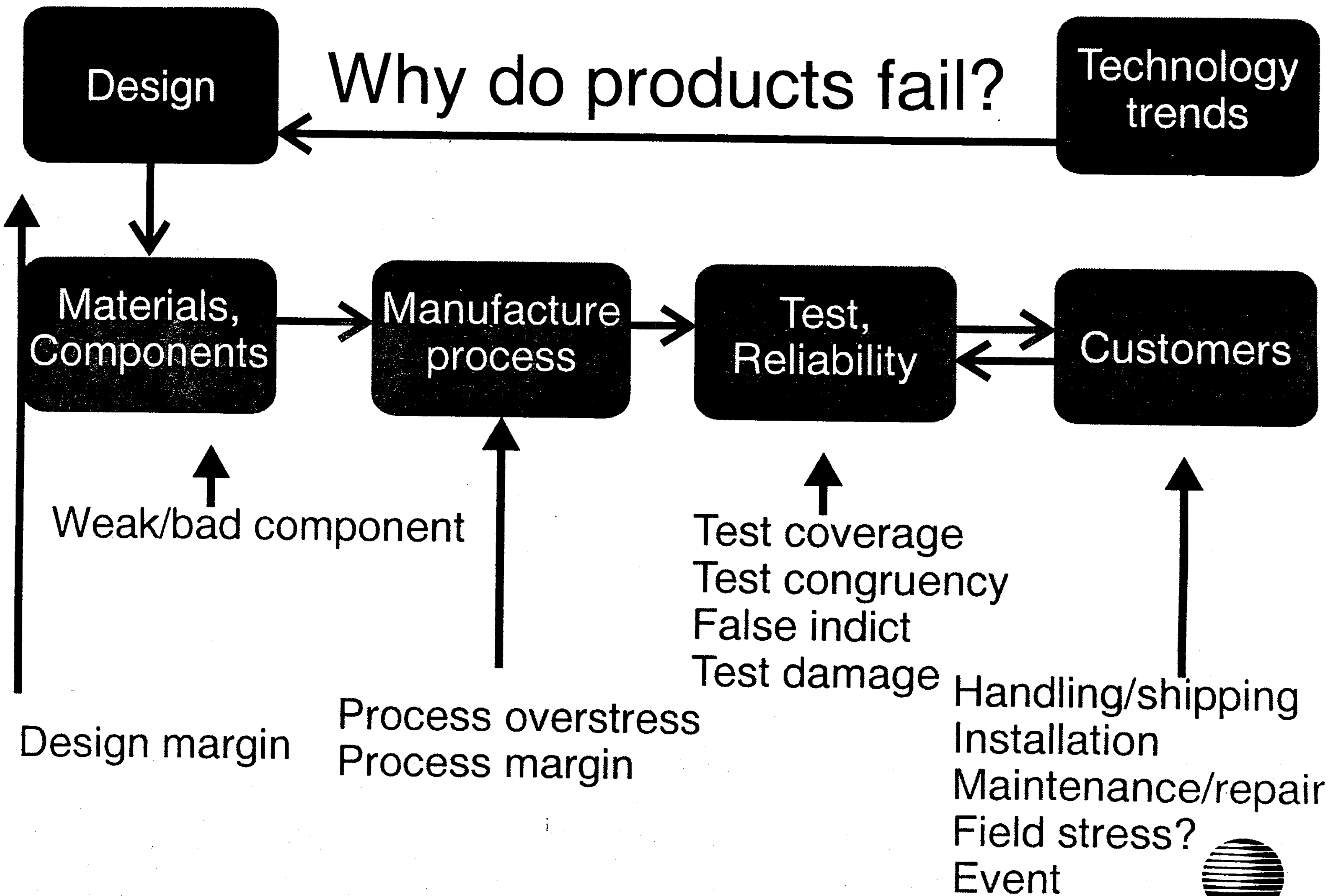
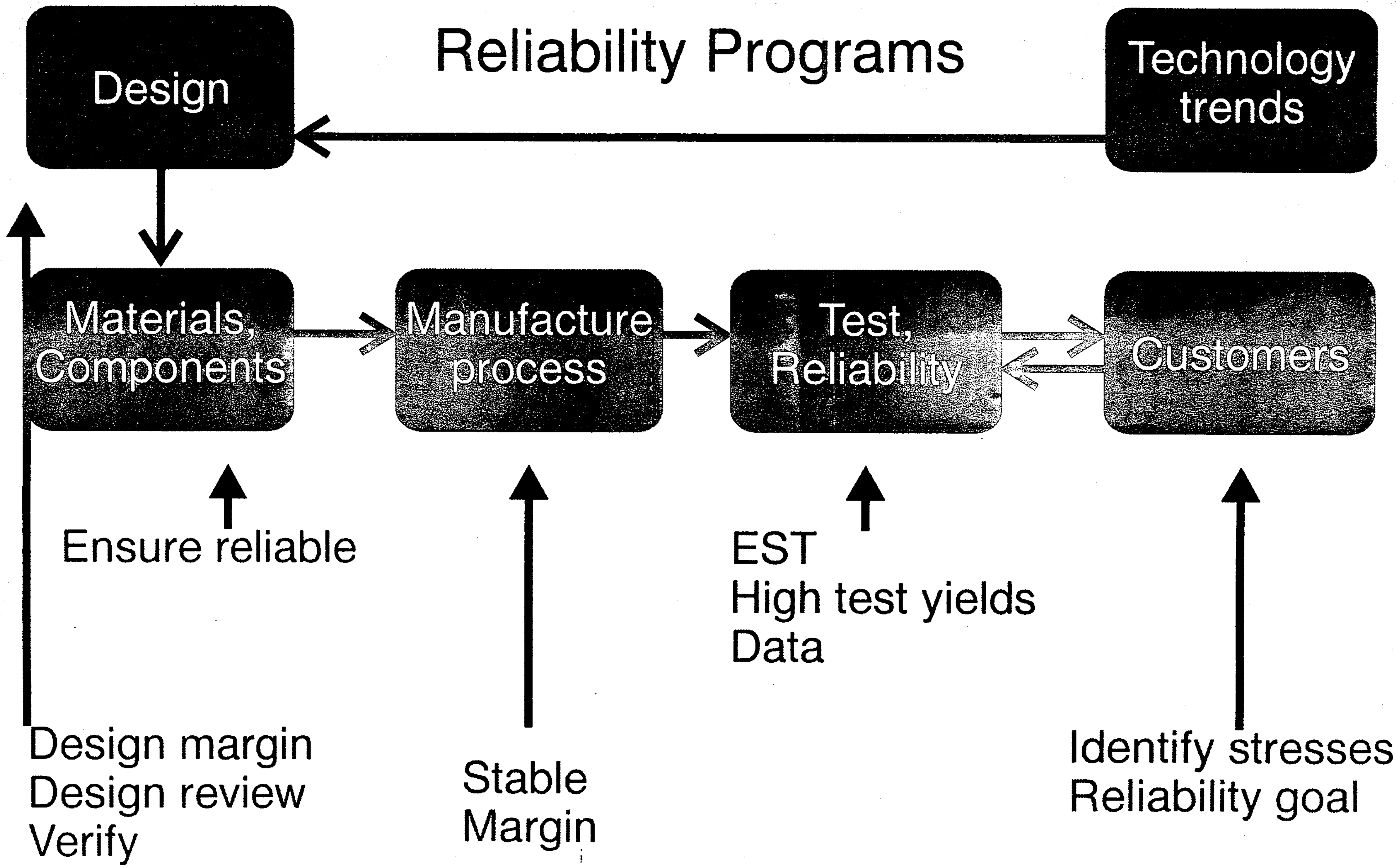
Why do products fail?



Reliability Programs



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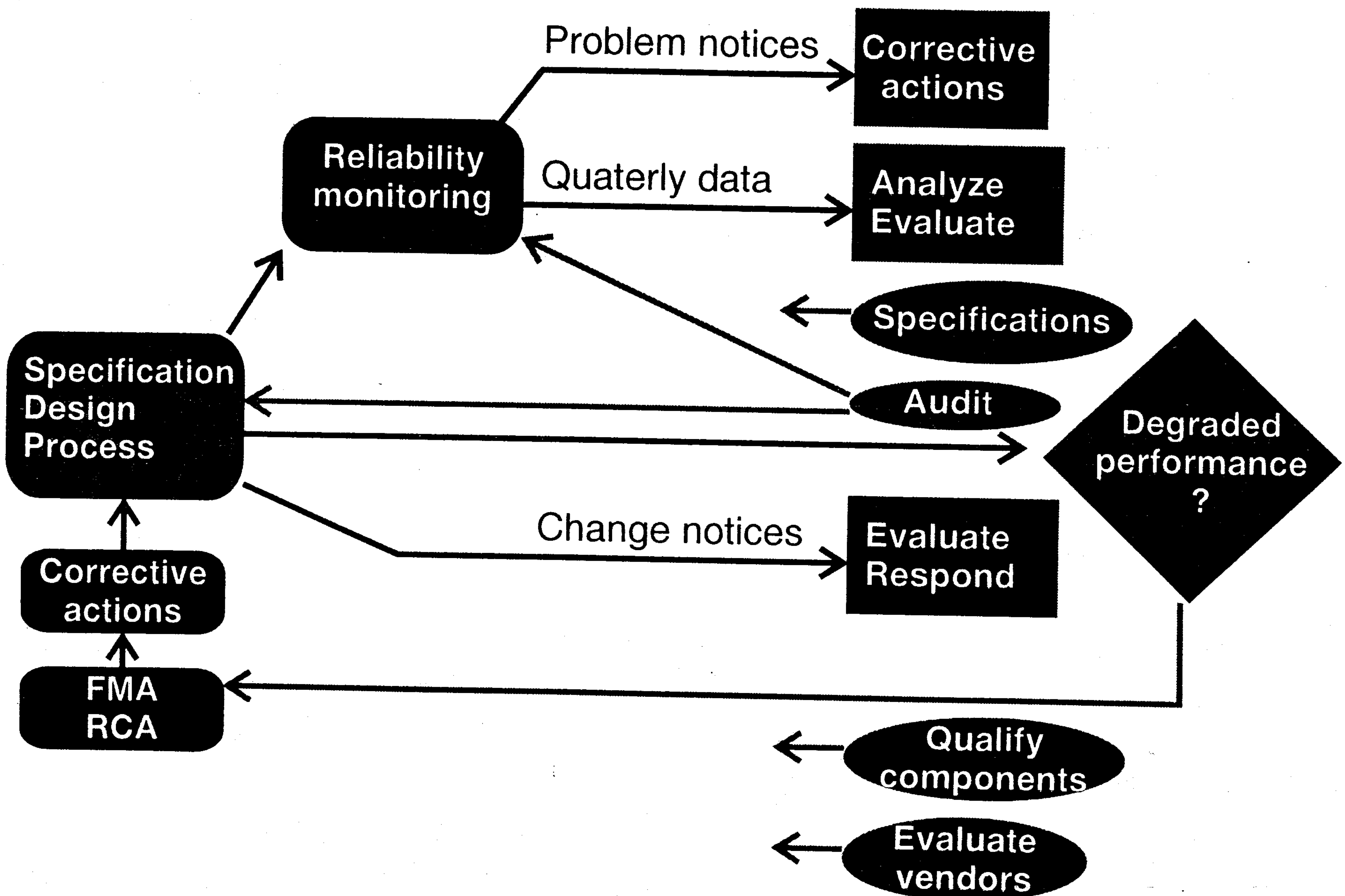
Component/Supplier Specification Program



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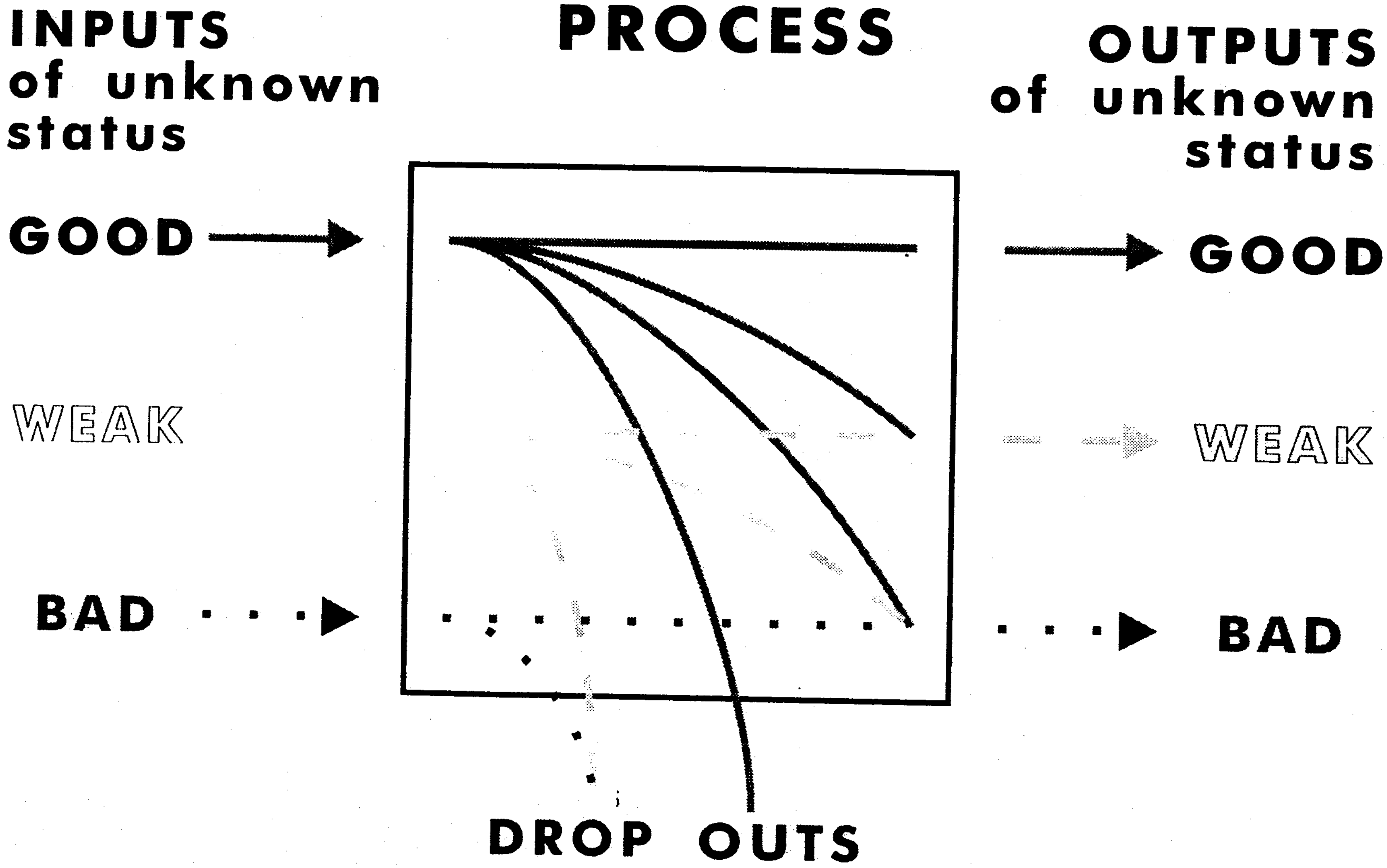
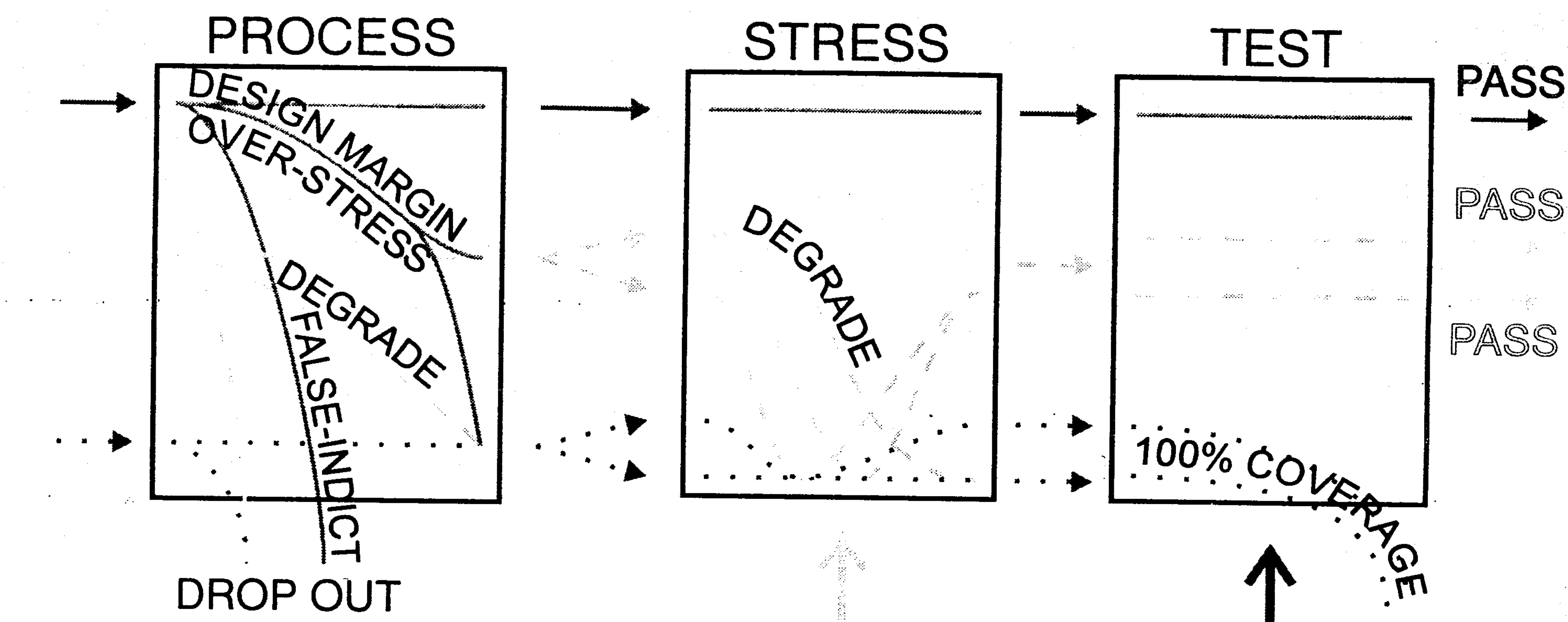
Failure, Analysis, Corrective actions Database

LOGISTICS	FAILURE	ANALYSIS	CORRECTIVE ACTION
Model # Part # Serial #	Symptom	FMA results	Recomended action
	Effect		Taken? When & by Who?
Where failed	Operating mode		Verified?
When failed	Environmental conditions		
Who reported	Failure category		

GENERALIZED OPERATOR PROCESS

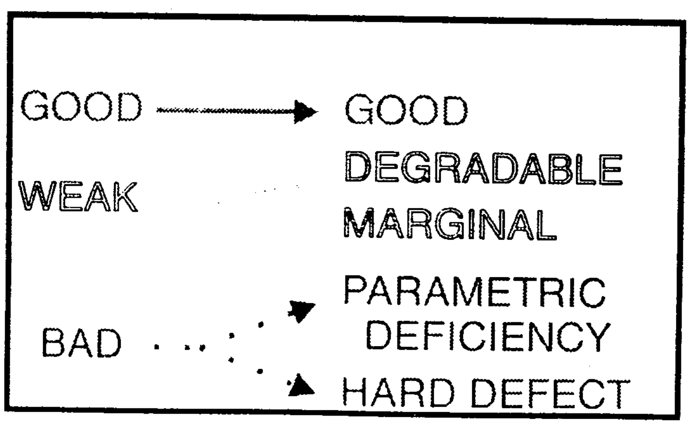


GM&E ERC CHAN ST9401.01



The weak units bahave bad only under/after the right stress conditions.

The ideal test will find all bad units only.



BAD UNITS RESULT IN FACTORY FAILURES.

WEAK UNITS RESULT IN FIELD FAILURES AND ARE EXHIBITED BY STRESSES.

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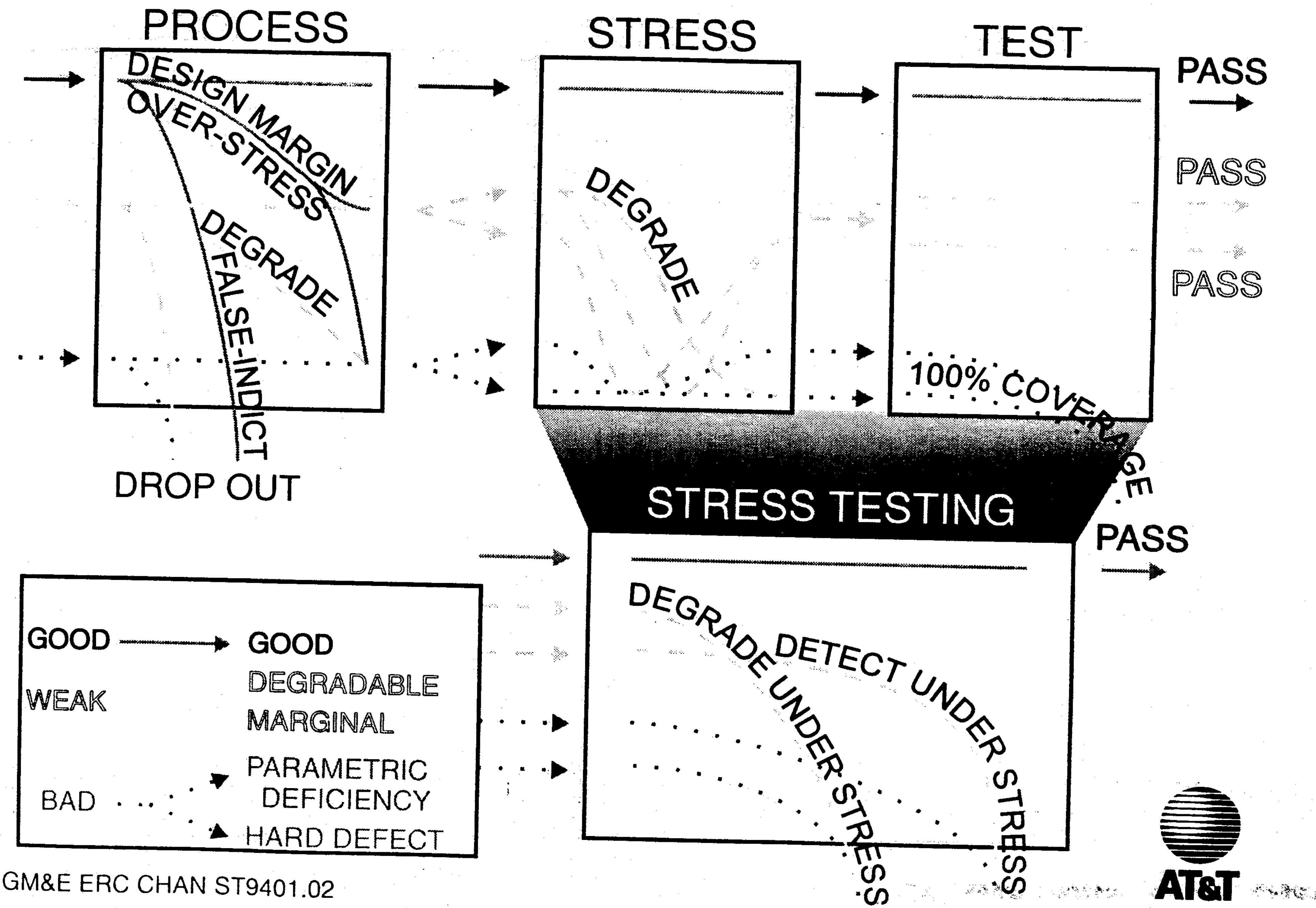

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Screening vs Stress Testing

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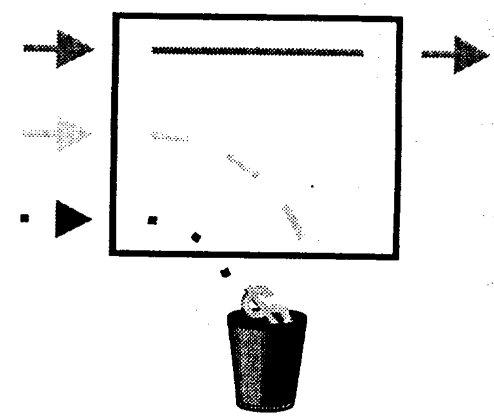
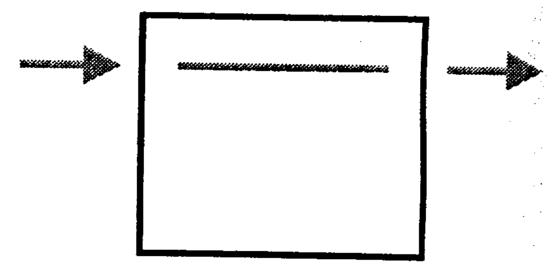
Environmental Stress Screening (ESS)



- Apply stresses to stimulate observable failures for weak units.
- Weak products are screened out, although they continued to be produced.

Environmental Stress Testing (EST)



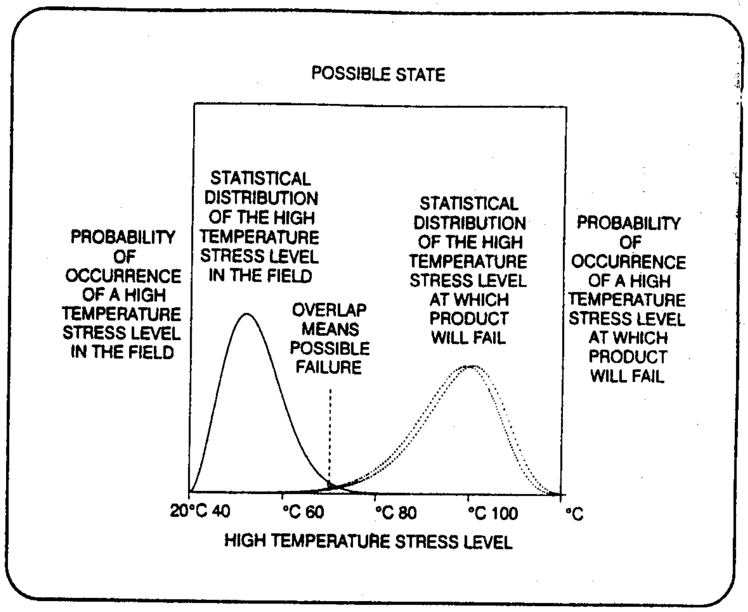
- Identify weaknesses of product to withstand stresses.
- Take corrective actions to achieve product robustness.
- Use sampling to monitor and maintain quality.

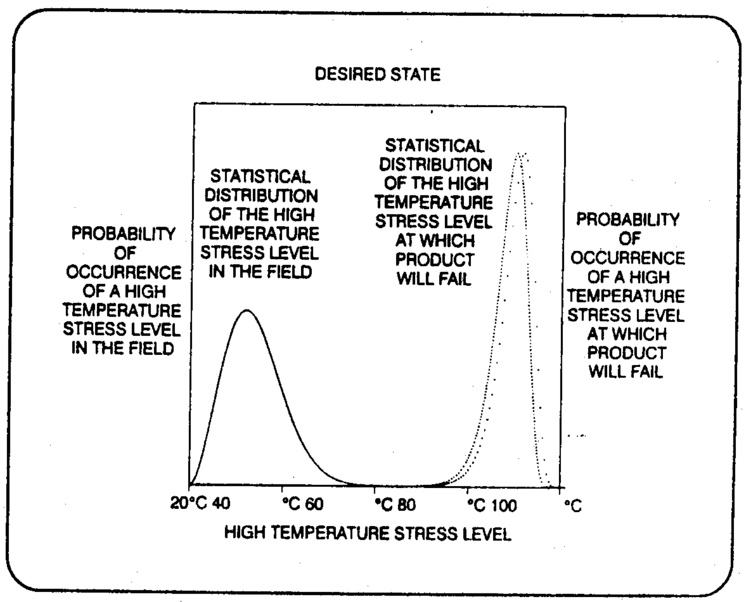
Rationale for stress testing.

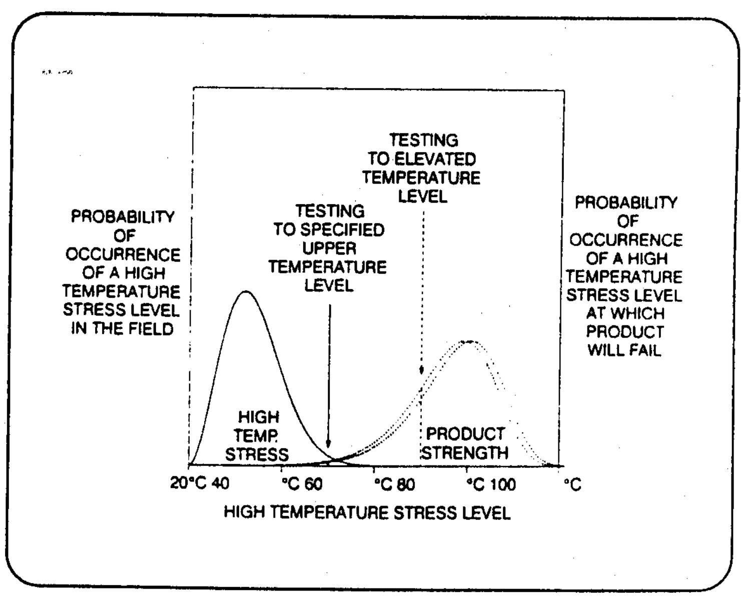
Environmental stress testing is an effective method for improving product reliability. Products may often have hidden defects or weaknesses, which can cause failures during normal operation in the field. Top viewgraph shows that product failures may occur when the statistical distribution for a product's strength, or its capability of withstanding a stress, overlaps with the distributions of the operating environmental stresses. To prevent product failures, reliability may be achieved through a combination of robust design and tight control of variations in component quality and manufacturing processes. Center viewgraph shows that when the product undergoes sufficient improvements, there will no longer be an overlap between the stresses encountered and product strength distributions. Stress testing is a process in which environmental stress stimuli are applied to a product to turn such latent defects into observable failures. The stress testing process thus prevents defective product from being shipped to the field, and offers an opportunity to discover and correct product weaknesses early in product life.

Bottom viewgraoh shows that product variations are better revealed at heightened stress levels. The stress levels applied must be severe enough to precipitate the defects without causing damage to good product or nucleating defects, which cause early wear-out and reduced life in the field. Application of stress testing accelerates the process of precipitation and detection of latent defects.

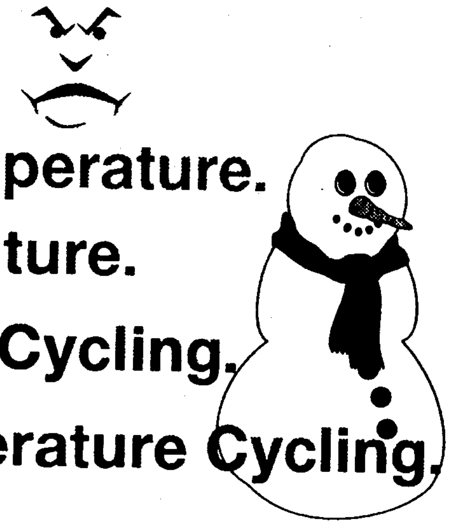
Stress screening has its origins in the space program in the 1960's, which required 100% defect free systems. While quality control was the ultimate objective, there was not much attention paid to cost of doing stress screening. Subsequently, in the 1970's, stress screening was adopted by the defense electronics industries, as an effective technique for quality control. Much of the pioneering work to quantitatively establish the benefits of stress screening was done by the defense electronics industry. Defense contractors are contractually obligated to perform stress screening on 100% of their final shipped products, which can be a costly process. More recently, stress screening has been routinely applied in the commercial electronics industries, as well, and the number of commercial users is increasing at a rapid rate. While defense electronics industries apply stress screening as a contractual obligation, commercial industries have effectively applied stress testing as a tool for improving quality, while also making it cost more effective.







Stress Stimuli

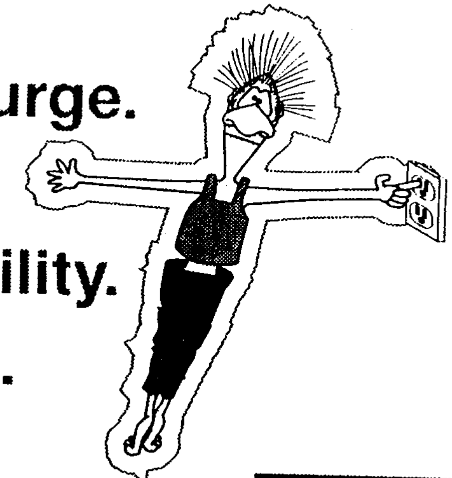


Elevated Temperature.

Low Temperature.

Temperature Cycling.

Liquid Temperature Cycling.

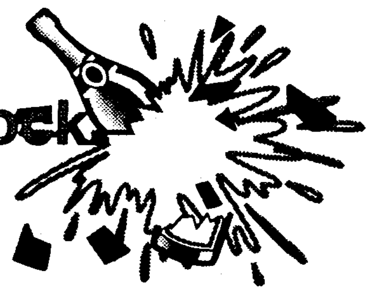


ESD, Power Surge.

EOS

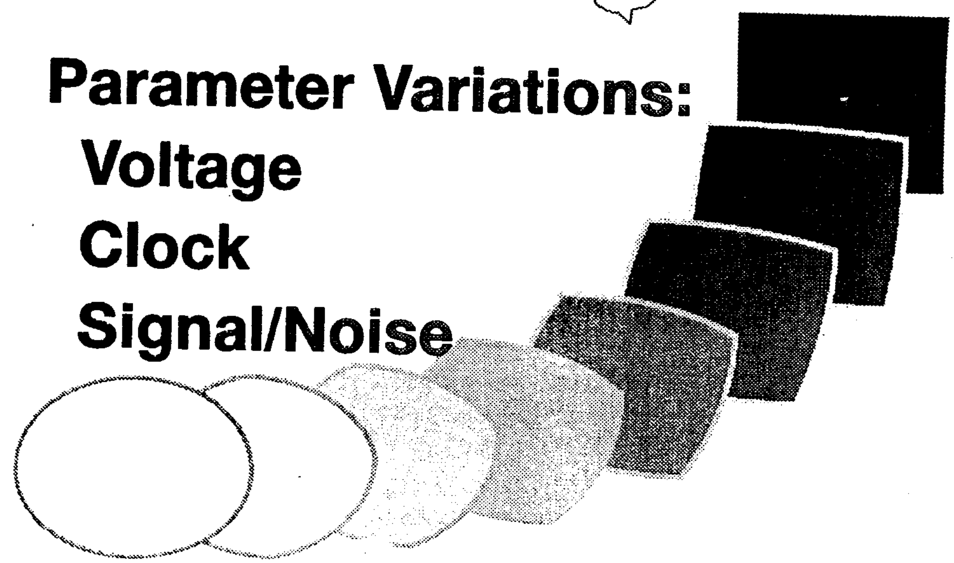
EMI Susceptibility.

Power Cycling.



Vibration.

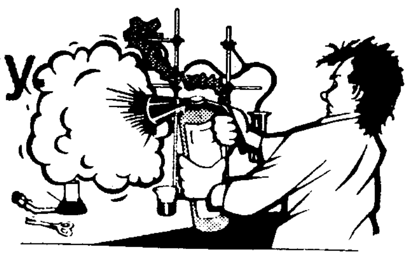
Mechanical Shock



Parameter Variations:

- Voltage
- Clock
- Signal/Noise

Elevated Humidity



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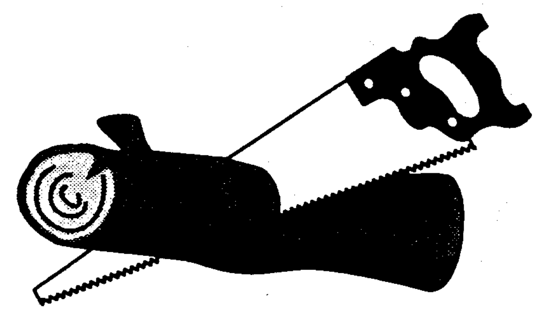
What Failure Type Dominates?

Threshold stress failure.

- A high peak-stress encountered during assembly, handing, transportation, installation, or field use stimulates failure.
  - Breakdown electric field of device.

Cumulative stress failure.

- Stresses encountered over the entire product life causes cumulative damage.
  - Electromigration.



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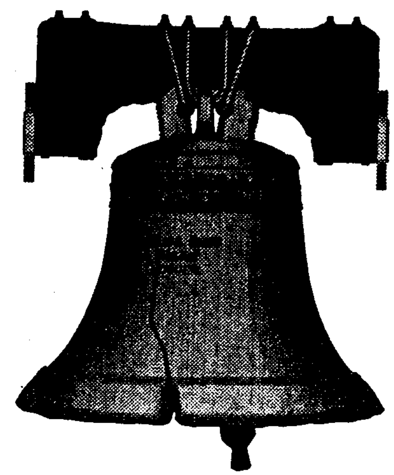
What Failure Type Dominates?

Combined threshold-cumulative stress failure.

- A high peak stress initiates an incipient failure site which is then driven to a hard failure by subsequent cumulative stress.
- Cracked component package followed by corrosion.



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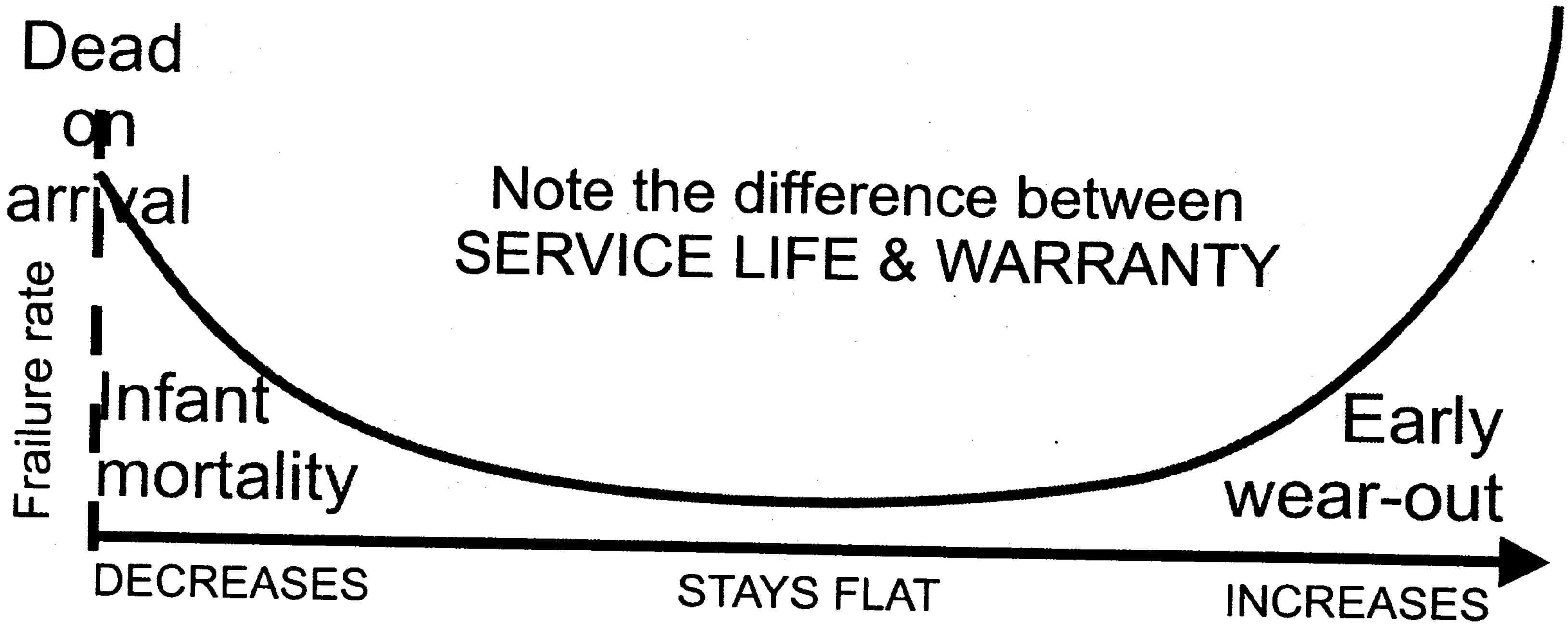
Product Reliability - avoidance of failures, which ***customers*** see over product life



Cumulative fraction failed, F(t),
fraction of product units that have (first) failed up to time t.

Lifetime failure rate, LFR,
cumulative fraction failed over the entire service life, F(service life).

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From Where are Failures Coming?

Product strength distribution:

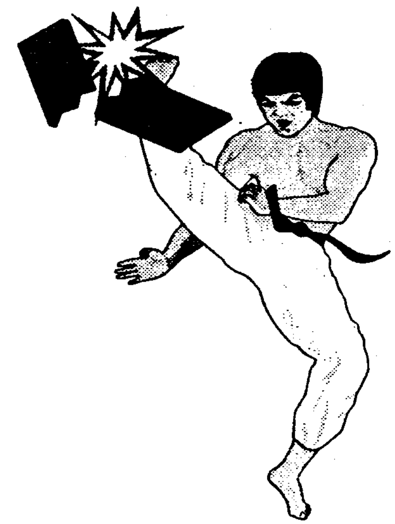
- Main population
- Weak populations

Sources of infant mortality and freak failures:

- Mainly from weak populations.
- Some early wear out from low strength shoulder of the main population.

LIFETIME MAXIMUM STRESS, X

DEPENDS ON CUSTOMERS' STRESS ENVIRONMENT ONLY

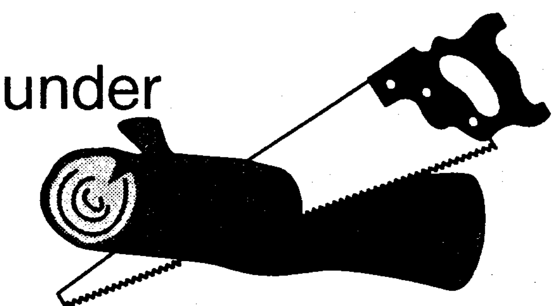


Threshold stress failure.

- Highest stress level ever encountered by a unit during its entire service life under a certain customer's environment.
  - e.g. coldest environmental temperature.

Cumulative stress failure.

- Total effect made by stresses on a unit accumulated over the entire service life under a certain customer's environment.
  - e.g. 60C and 8V over 1,000 hours.



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PRODUCT (YIELD) STRENGTH, Y

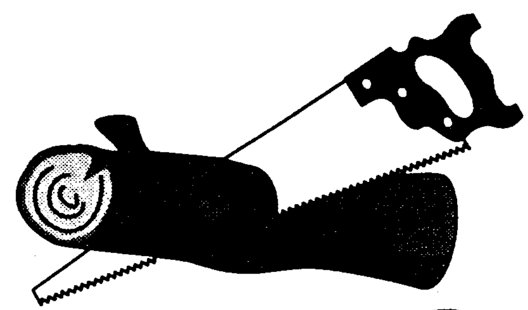
DEPENDS ON THE ROBUSTNESS OF THE PRODUCT ONLY

Threshold stress failure.

- Highest stress level a unit can endure without exhibiting first failure.
- e.g. I-V curve may shift too much to function properly at -30C.

Cumulative stress failure.

- Maximum effect from stresses a unit can endure without exhibiting first failure.
- e.g. electromigration failure after 60C and 8V over 1,000 hours.



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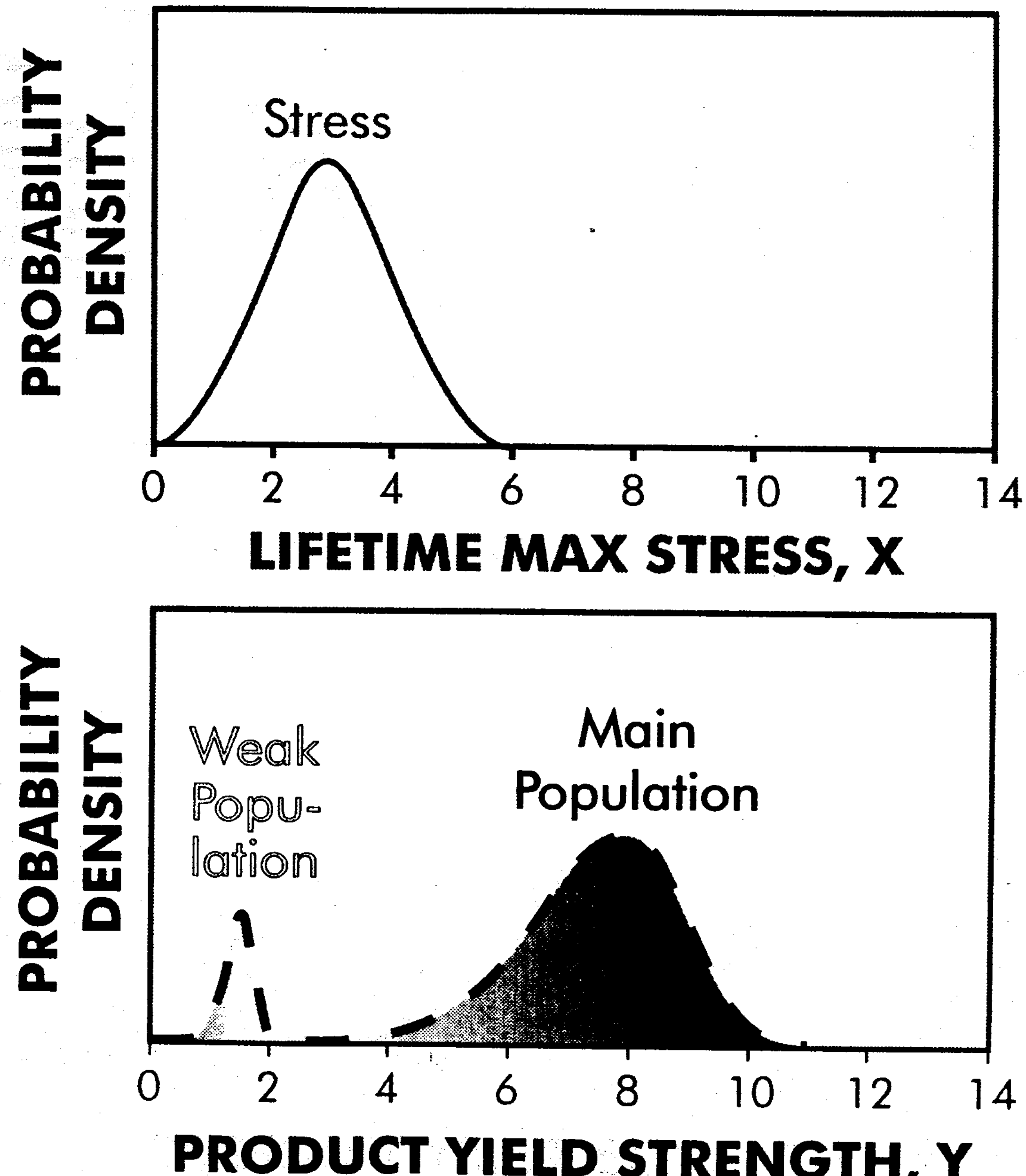
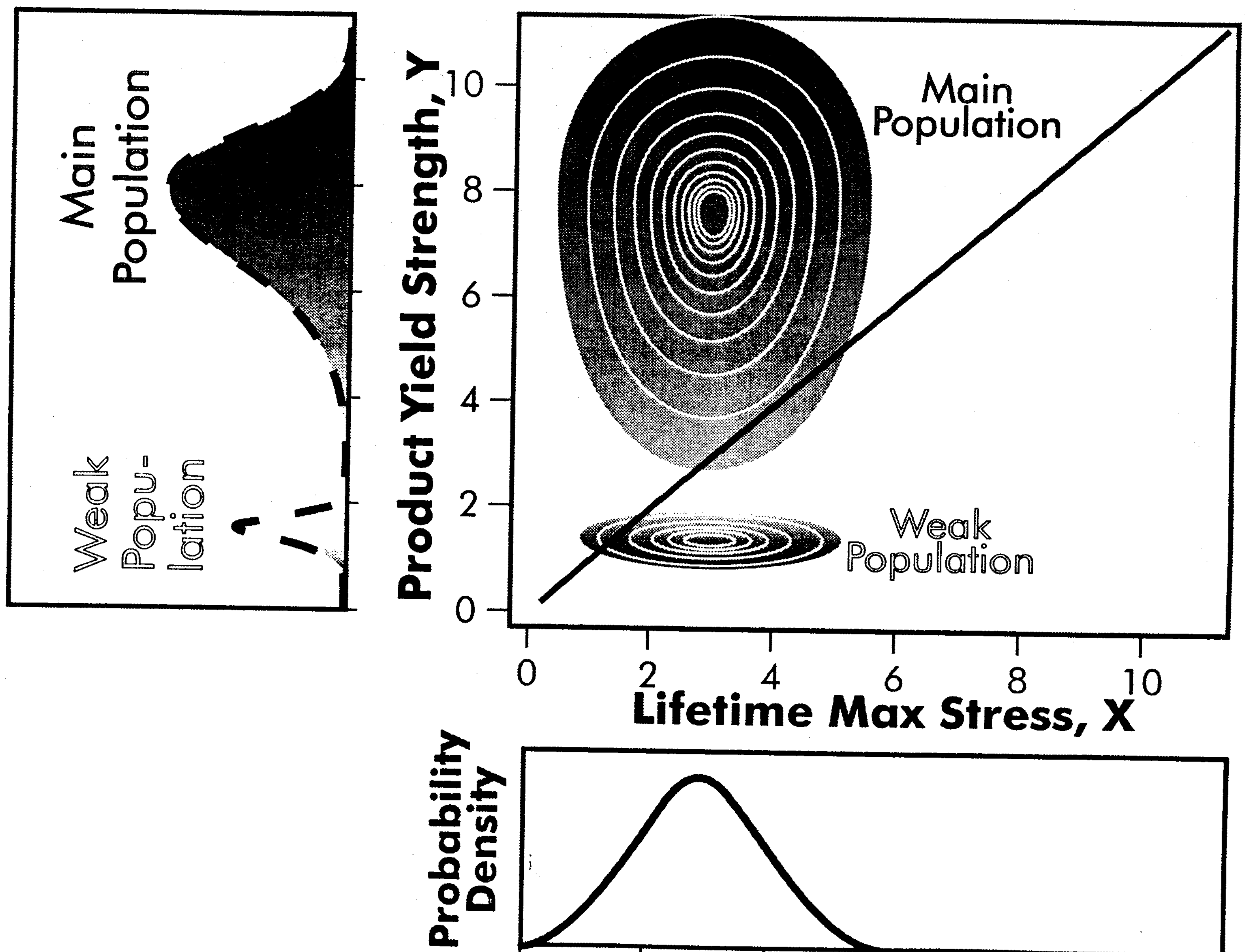


GM&E ERC CHAN CT9408.02

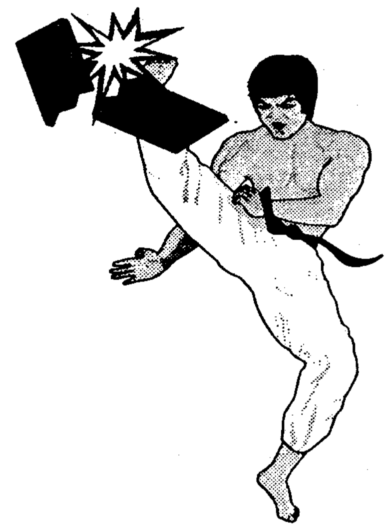

Main Population
Weak Popu-lation
Product Yield Strength, Y
0
2
4
6
8
10
Main Population
Weak Population
0
2
4
6
8
10
Lifetime Max Stress, X
Probability Density

MAXIMUM EST STRESS LEVEL, X^{ST}

DEPENDS ON STRESS TESTING ENVIRONMENT

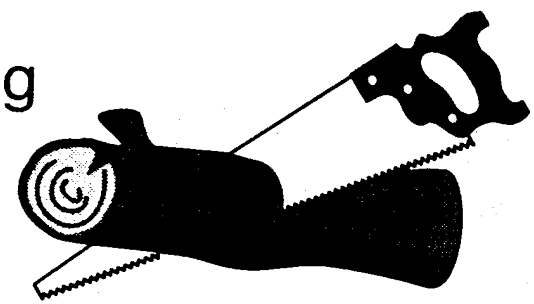
Threshold stress failure.

- Highest stress level ever encountered by a unit during the entire stress testing process.



Cumulative stress failure.

- Total effect made by stresses on a unit accumulated over the entire stress testing process.



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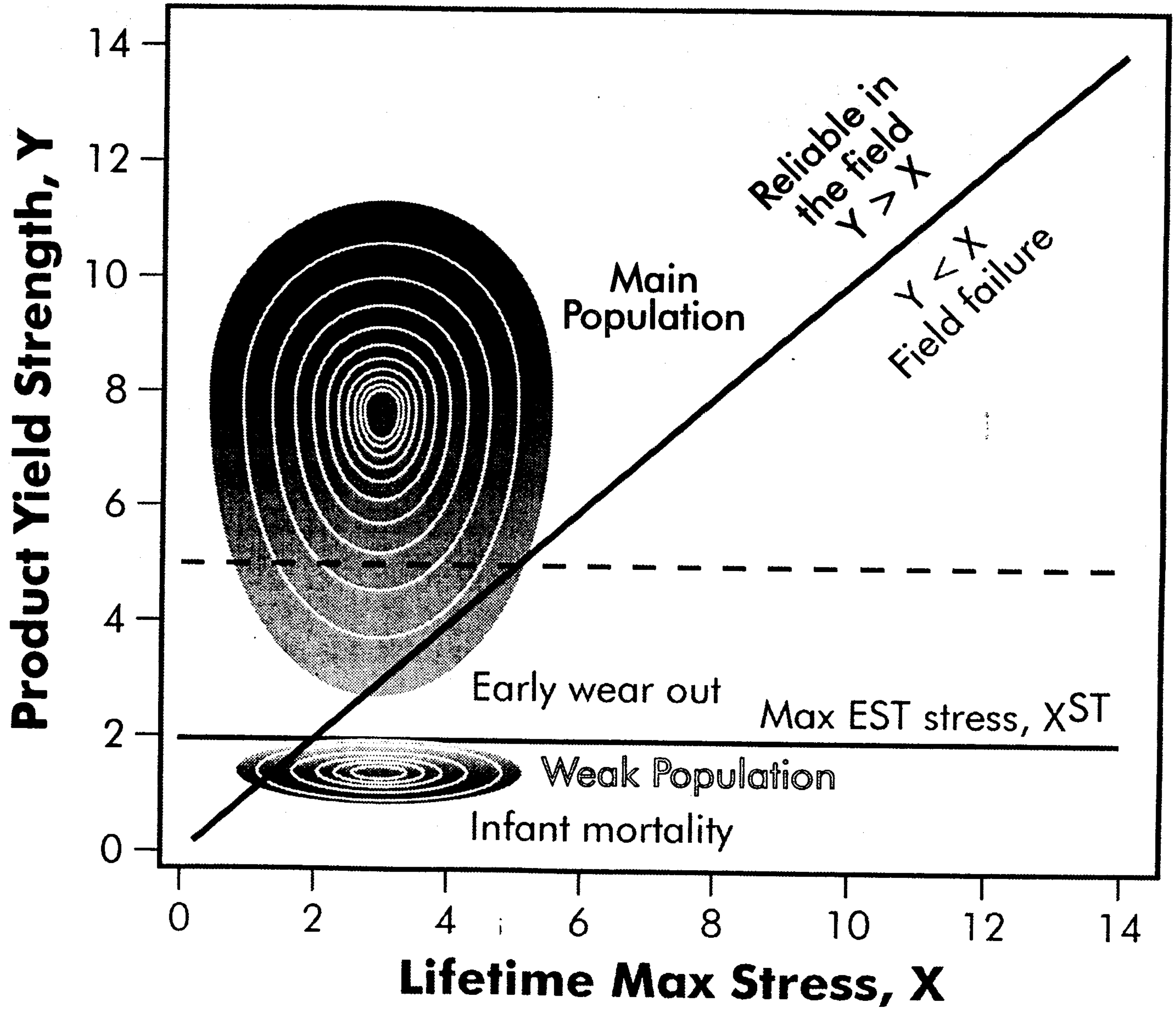

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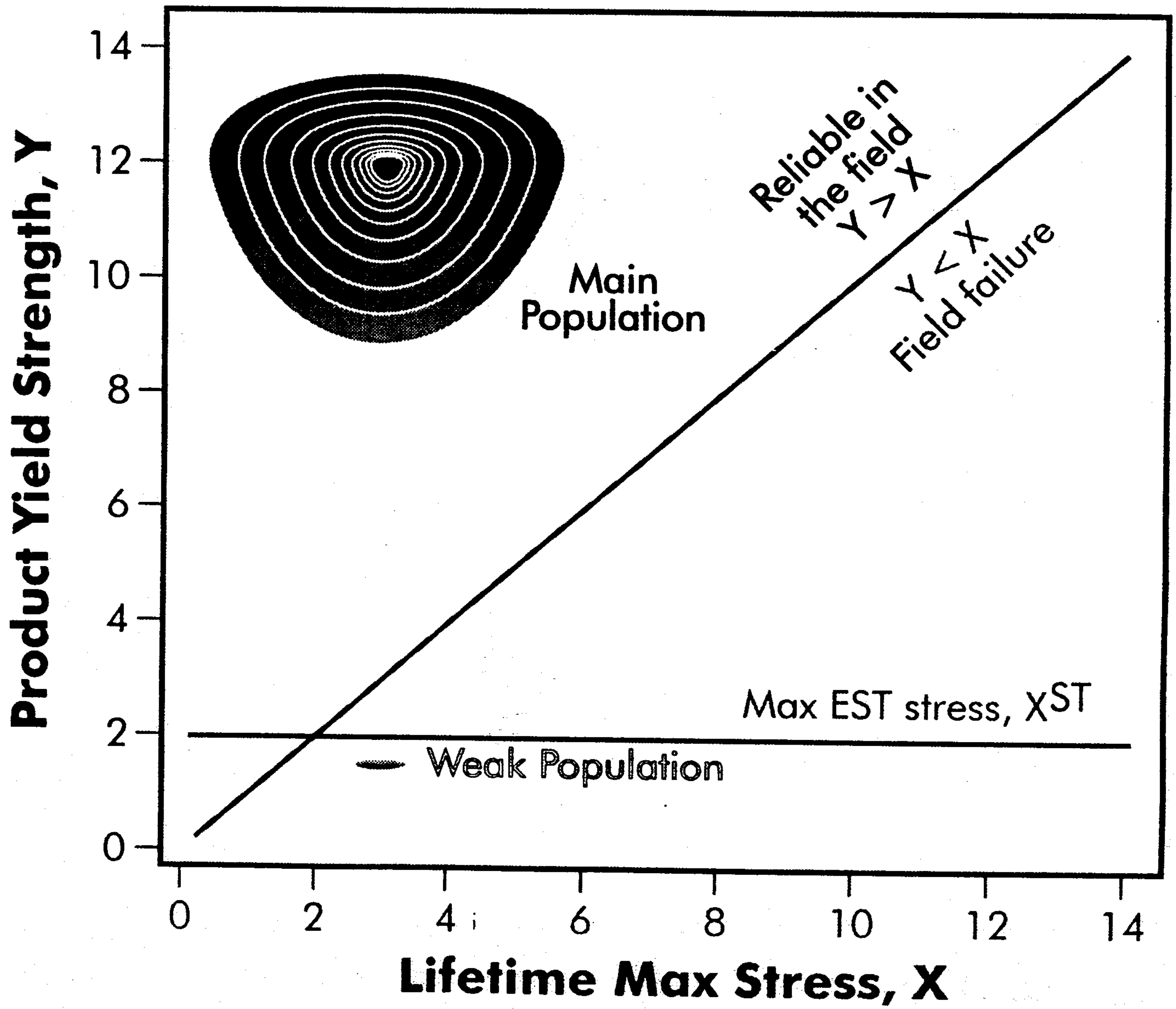

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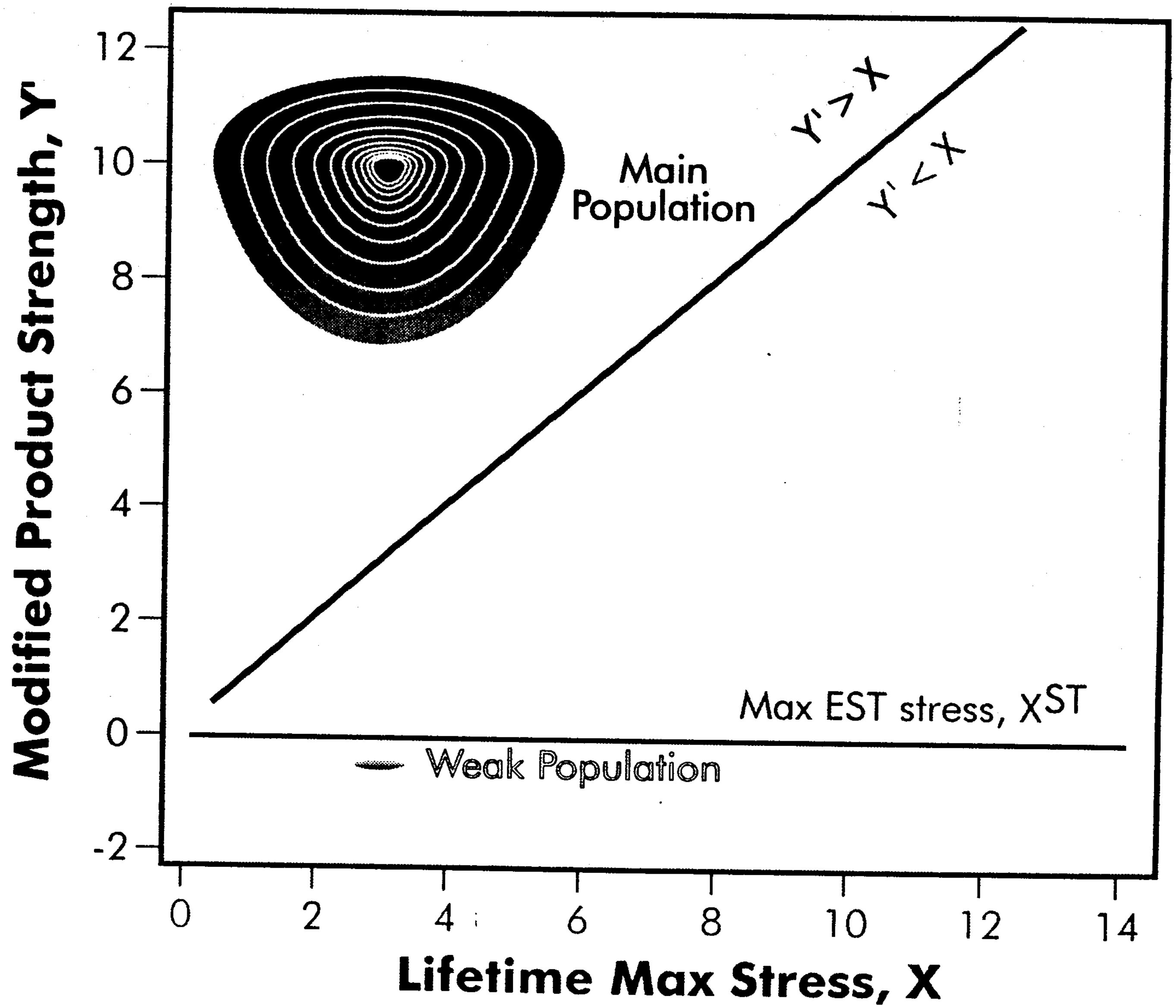

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Plastic Packaging and Burn-in Effects on Ionizing Dose Response in CMOS Microcircuits*

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Michael C. Maher
National Semiconductor Corporation
David R. Alexander and Michael K. Williams
Mission Research Corporation
Ronald L. Pease
RLP Research Inc.

Presented to
SHARP Commercial and Plastic Components in Military Applications Workshop
16 November 1995
Indianapolis, Indiana

*This work was performed under NSWC-Crane Contract N00164-92-D-0009 and supported by funding from the Defense Nuclear Agency

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Motivation and Objective for Packaging and Burn-in Investigation

- **Motivation**

The use of plastic encapsulated commercial-off-the-shelf (COTS) parts is being encouraged for weight and cost savings in systems which may be exposed to ionizing radiation from either natural space or nuclear radiation environments.

- **Objective**

To compare ionizing dose radiation effects on CMOS microcircuits as affected by plastic versus traditional ceramic packaging and by the application of burn-in as a reliability screen.

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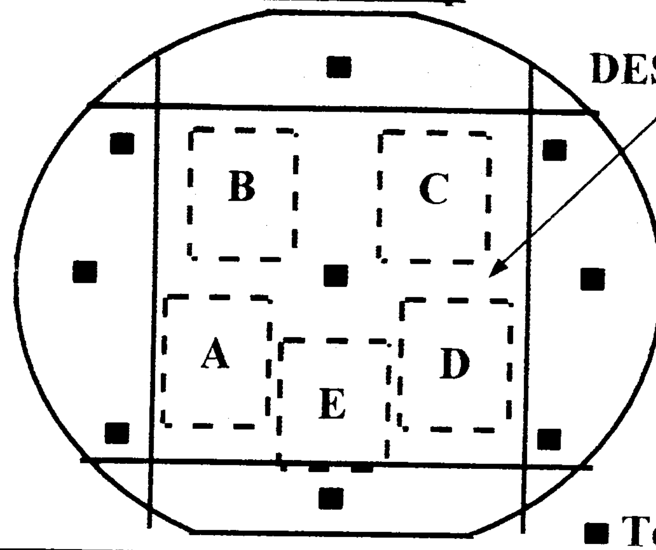
Test Population Summary

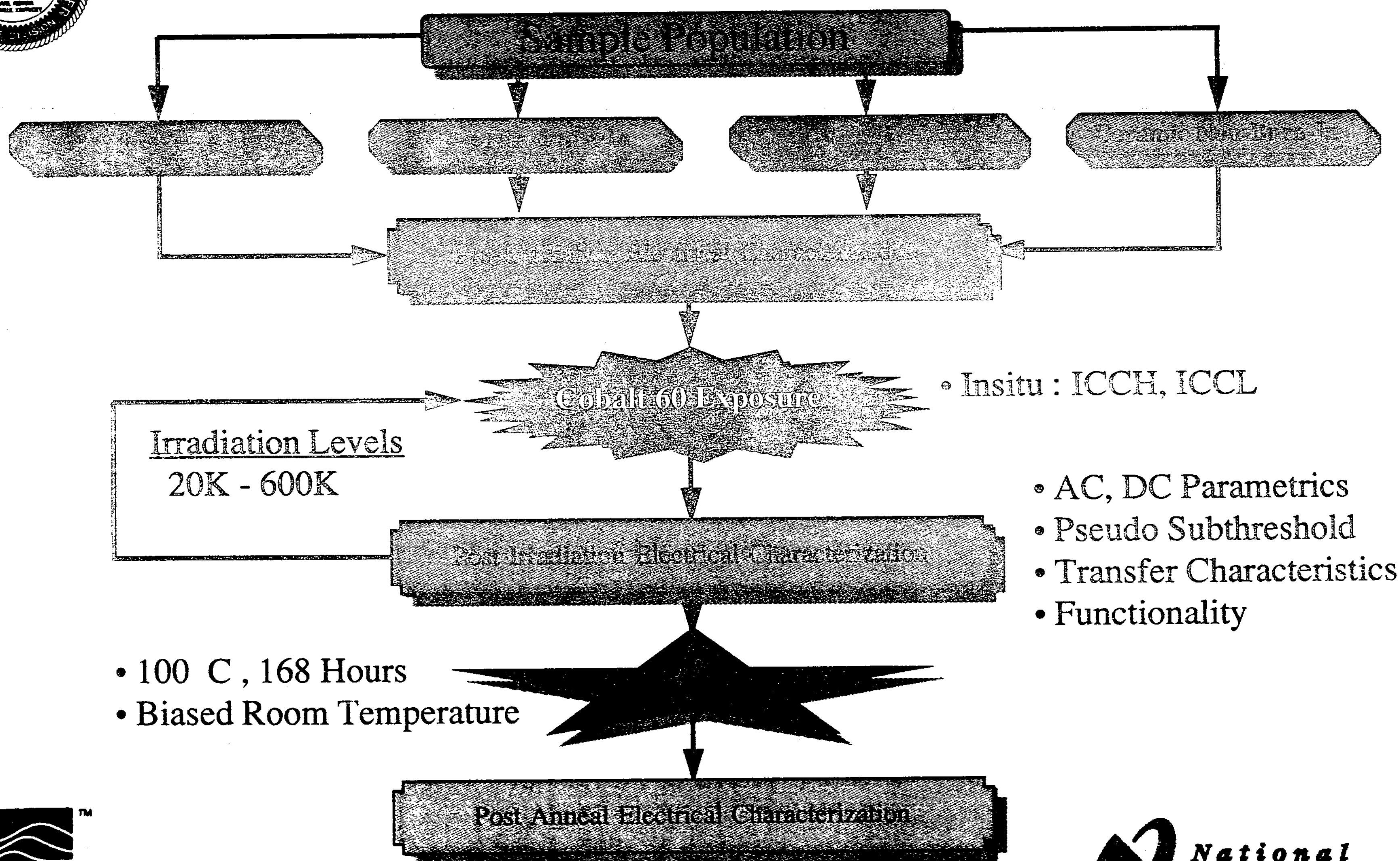
- Product Sample Description
  - Manufacturer : National
  - 54AC02 Quad 2-Input NOR Gate
  - JAN B, MIL-PRF-38535 Class V
  - Process Technology : Pwell Epi-CMOS, LOCOS isolation, TOX = 250 Angstroms

Wafer Map



Package Type	Burn-In	Package Mfgr.	# Samples
Plastic	No	NSC	33
Ceramic	No	NSC	79
Plastic	Yes	NSC	37
Ceramic	Yes	NSC	75
Plastic	Yes	SEI	63
Plastic	No	SEI	61

Product Sample Test Flow



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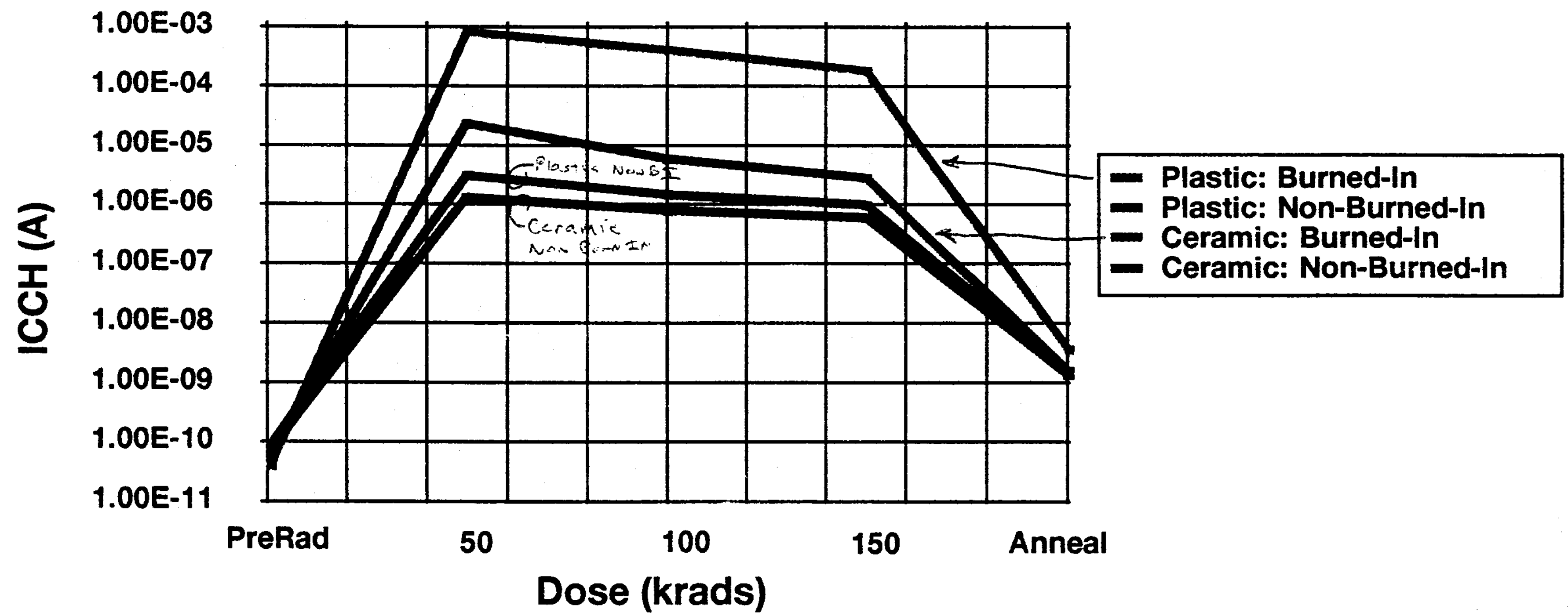
ICCH Max vs. Dose/Anneal for Four Groups at High Dose Rate



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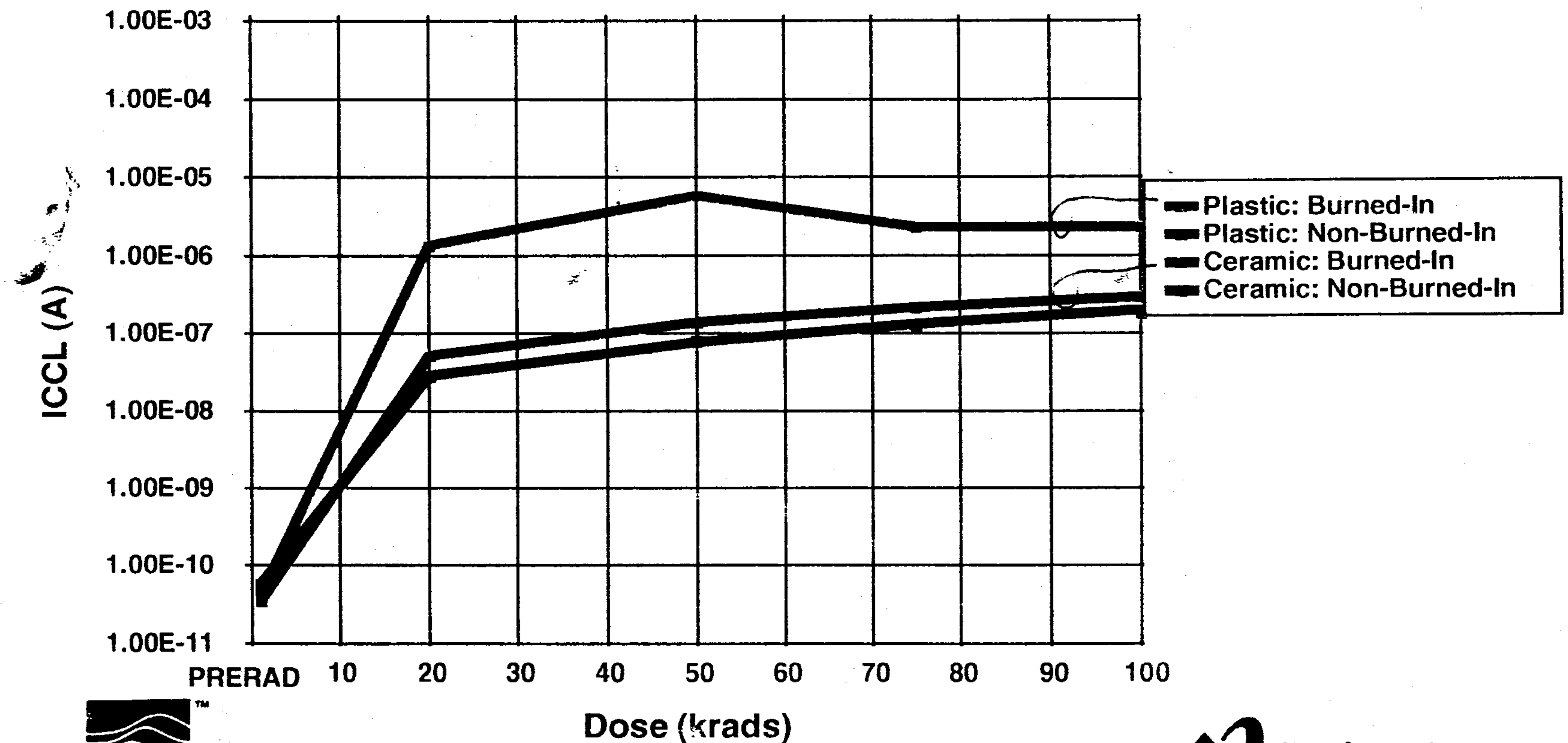
ICCL Max vs. Dose for Four Groups at Low Dose Rate



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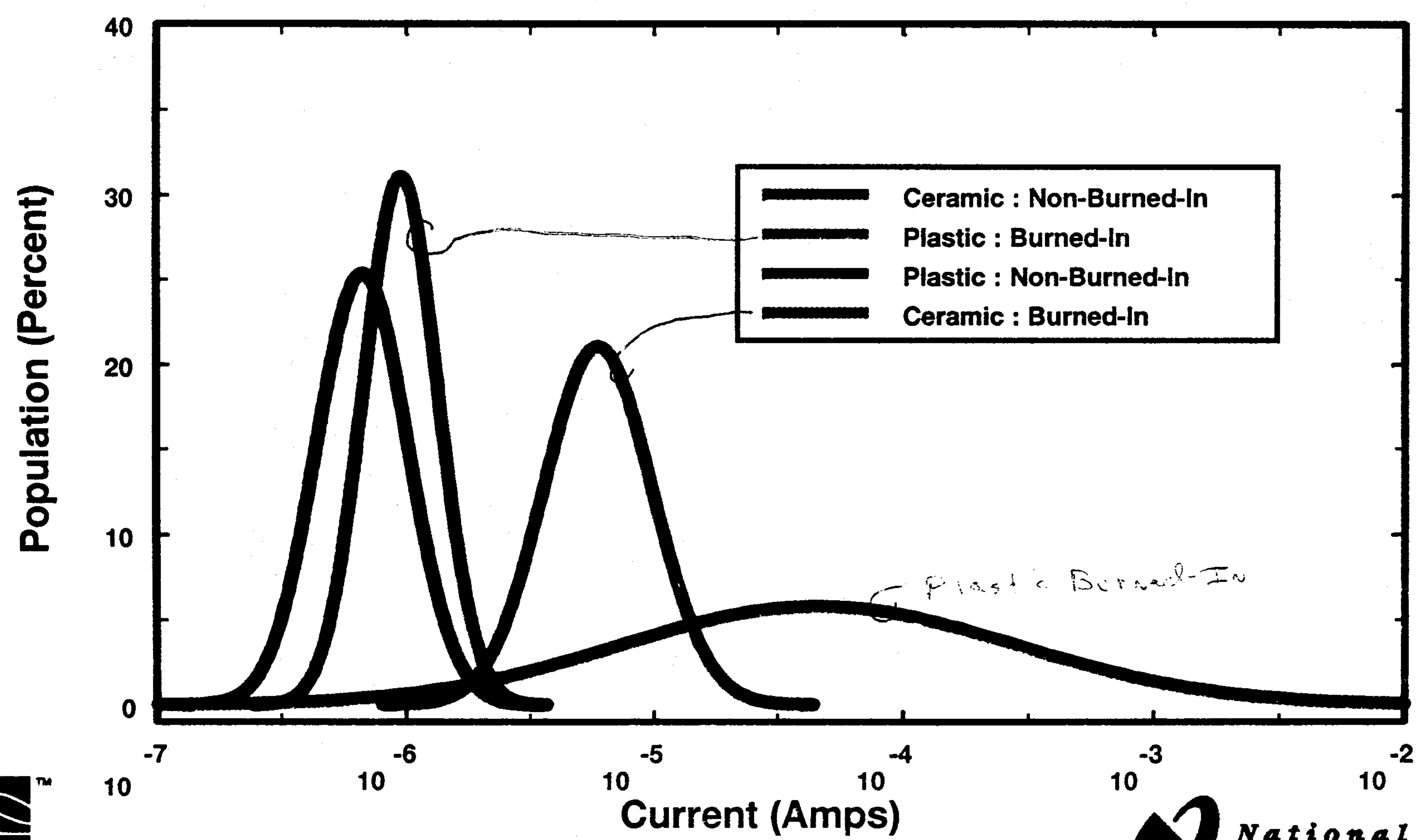
ICCH Population : 50K Rads

Normal Distribution : 50 Rad(Si)/Sec.



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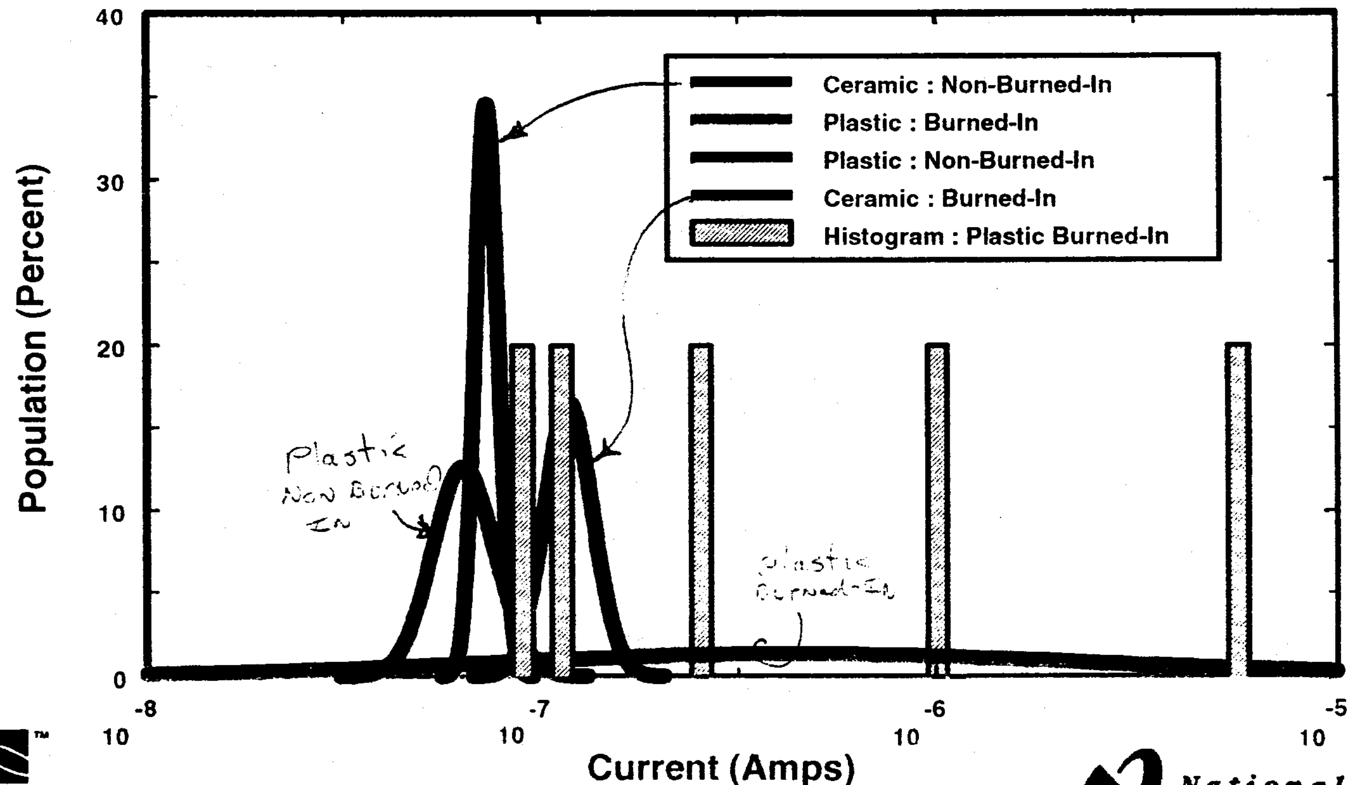
ICCL Population : 50K Rads

Normal Distribution : .096 Rad(Si)/Sec.



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Secondary Observations

- ICCH & ICCL annealing effects.
  - Rapid annealing following high dose rate exposure.
  - Minimal annealing following low dose rate exposure.
- ICCH & ICCL leakage paths.
  - N-channel source-to-drain edge path dominates high dose rate leakage.
  - Field oxide leakage path dominates low dose rate leakage.
- N-channel pseudo-subthreshold leakage correlates to post-irradiation ICCH & ICCL.

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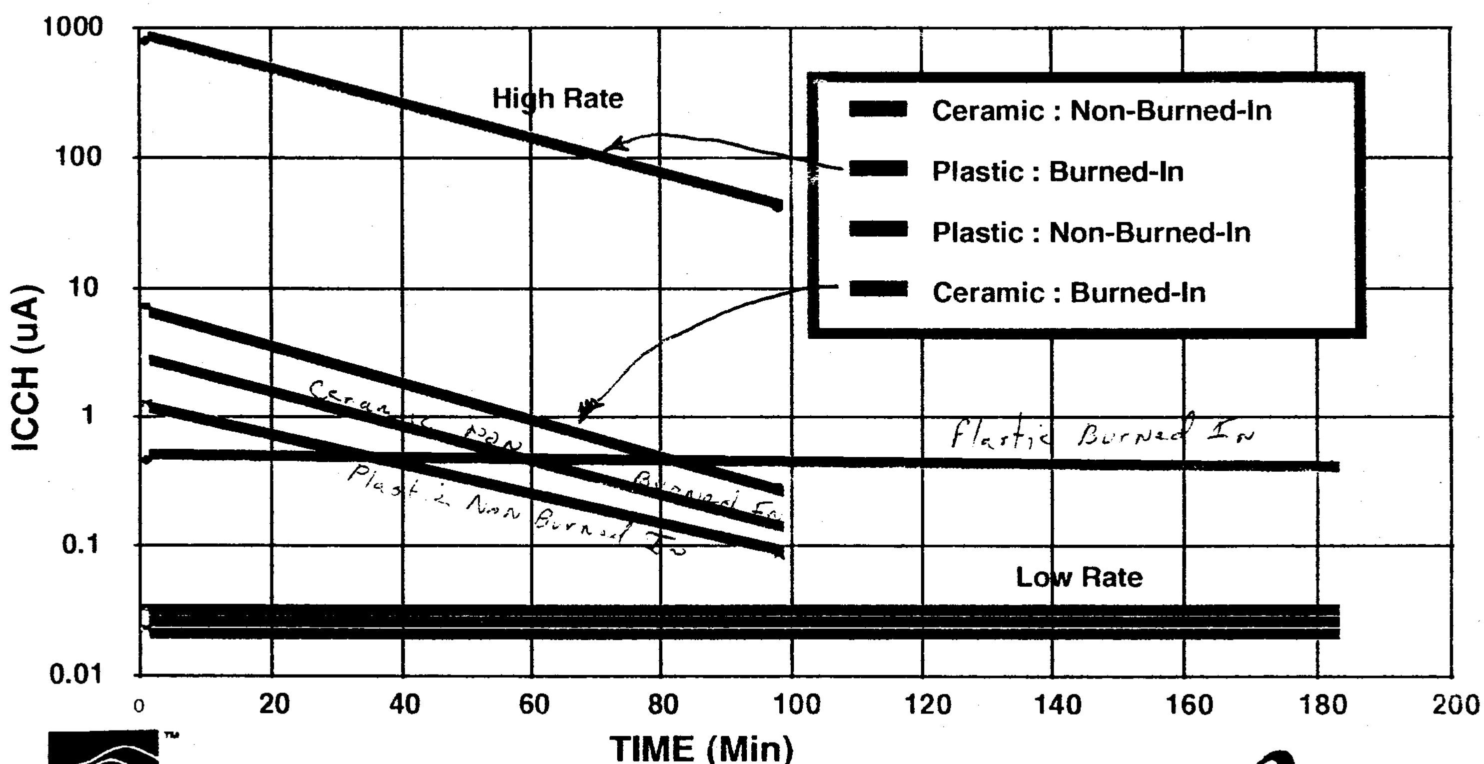
ICCH Anneal After 50 krads for High and Low Dose Rate



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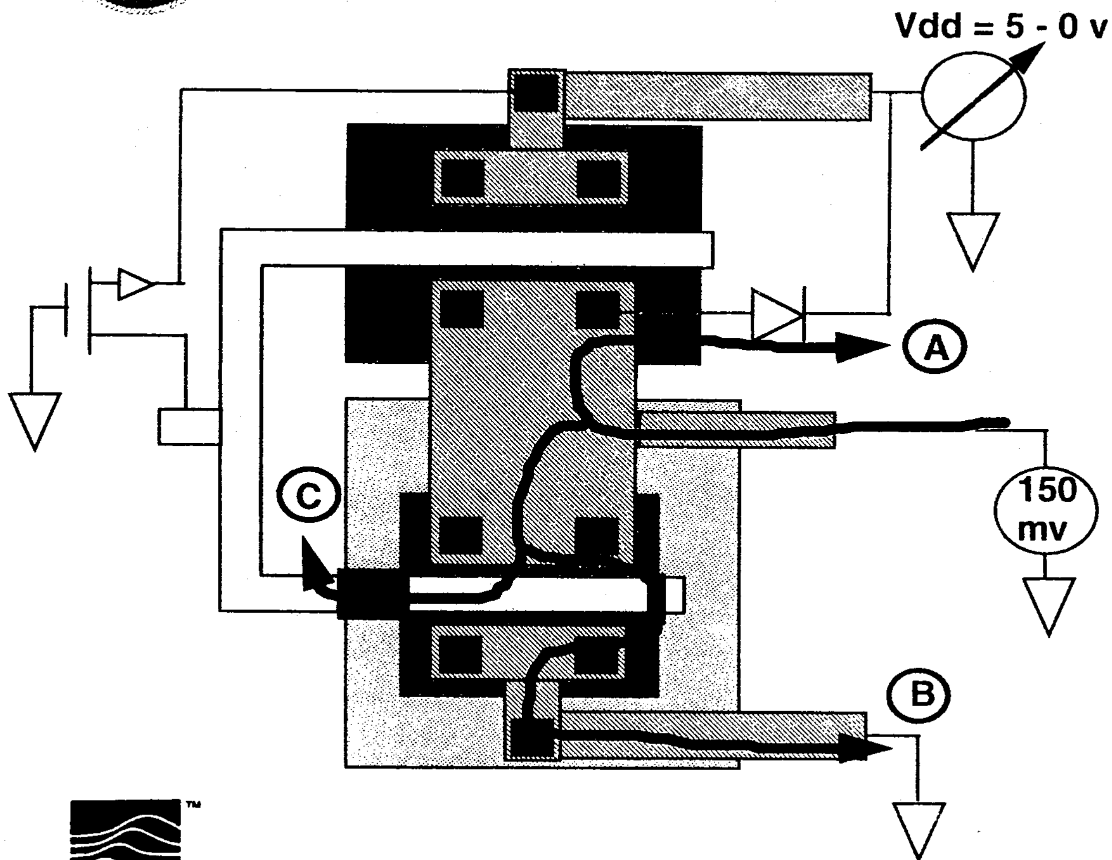
Cartoon of N-channel Output Stage Current Paths



- Path A: Parasitic diode dominates pre-rad currents for Vdd < 150 mv
- Path B: NMOS edge leakage dominates after high dose rate irradiation.
- Path C: FOX leakage dominates after anneal of high dose rate irradiation and after low dose rate irradiation.

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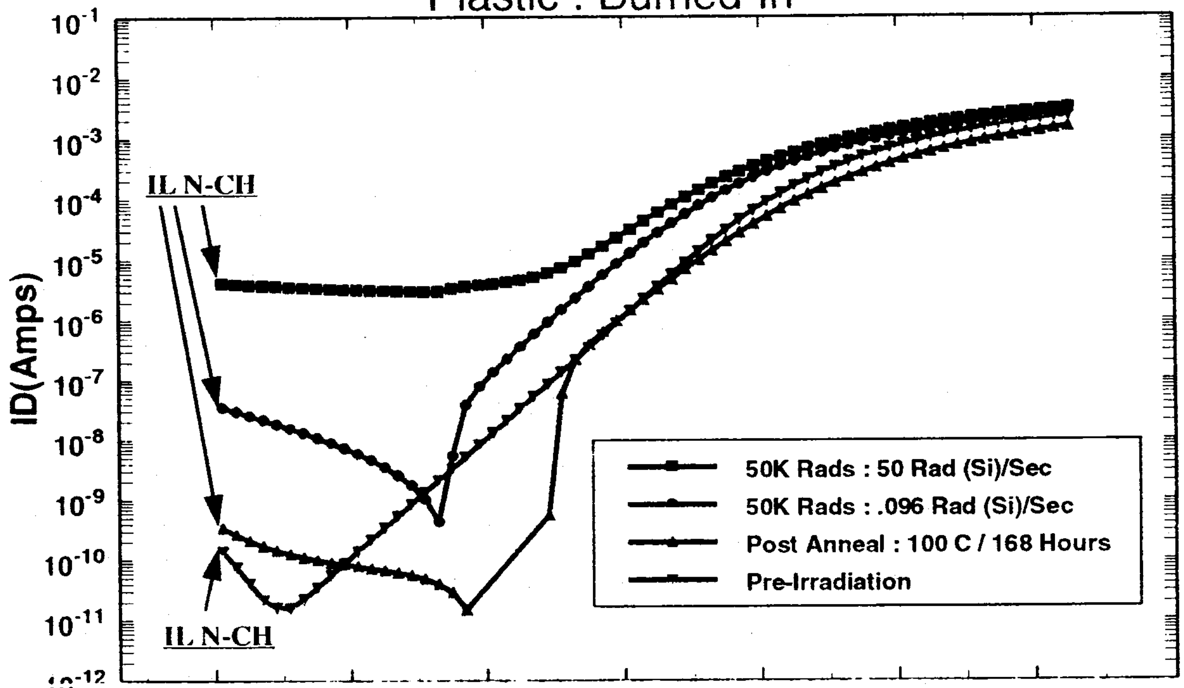
Pseudo SubThreshold N - Channel

Plastic : Burned-In



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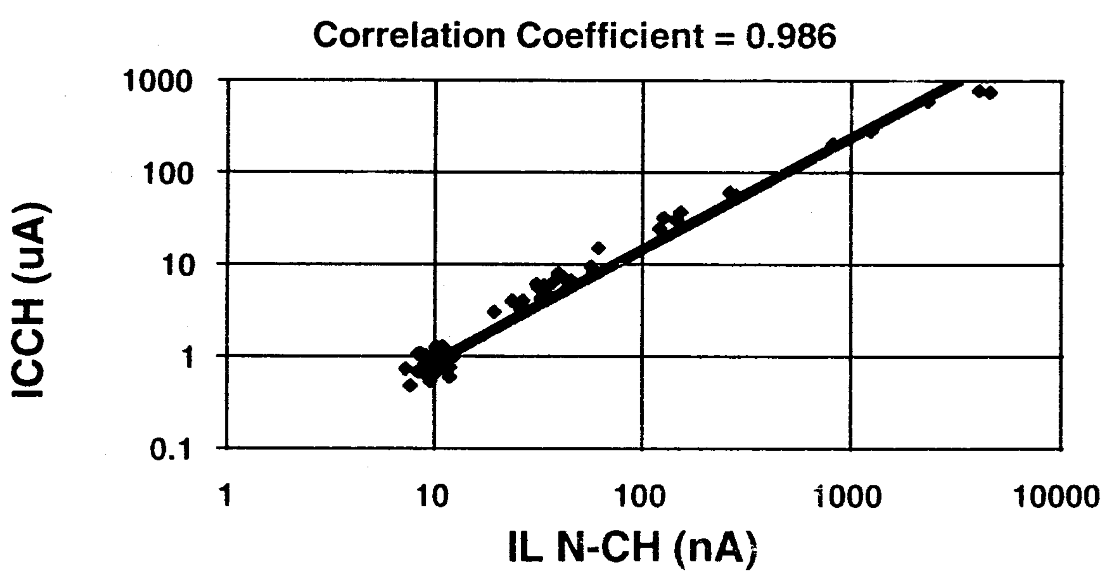
Correlation of ICCH and IL N-CH at 50 krads and 50 rads/s



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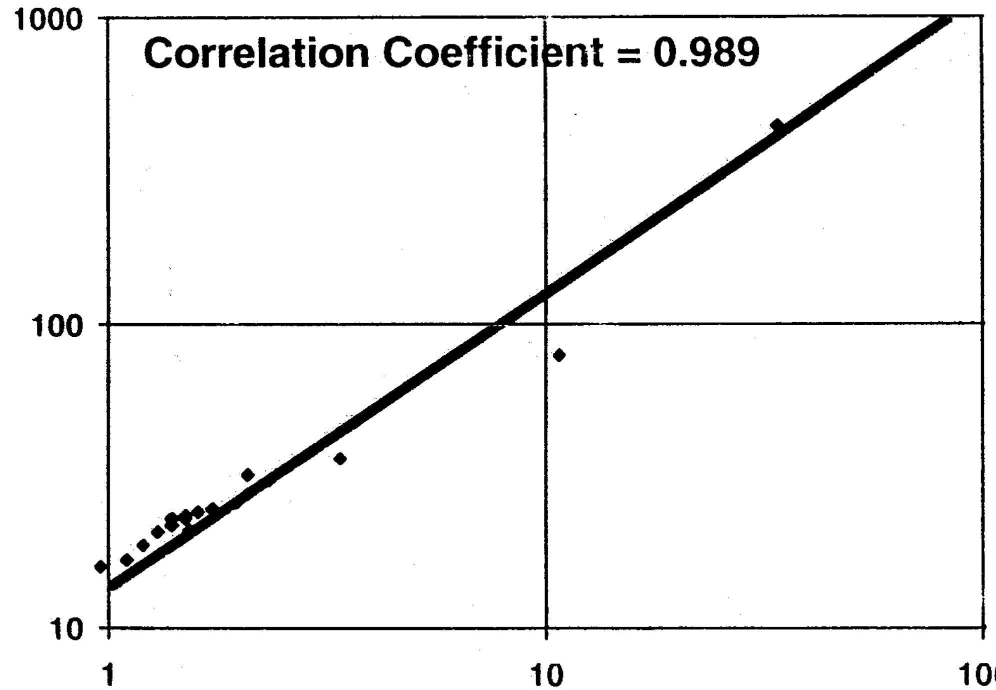
Correlation of ICCH and IL N-CH at 50 krad and 0.096 rads/s



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Summary of Packaging and Burn-in Investigations

- No parametric or functional total dose failures observed at or below 100 krad(Si).
- Plastic burned-in parts show enhanced degradation.
  - Worst case post-irradiation parameter values.
  - Broadest post-irradiation distributions.
- Degradation for low dose rate or high dose rate plus room temperature anneal is much less than for high dose rate.
- Analysis identified two leakage paths.
  - N-channel source-to-drain edge path dominates high dose rate effects.
  - Field oxide path dominates low dose rate effects.
- Mil-Std-883 Method 1019.4 part A is overly conservative for space applications of this technology.
- Physical mechanism for enhanced degradation in plastic/burned-in parts has not been identified.

Recommendations from Packaging and Burn-in Investigations

- Caution is recommended in using plastic/burned-in parts in systems with total dose requirements.
- Test samples should be representative of the flight population in terms of packaging and burn-in.
- Sufficiently large sample size is required for determination of radiation damage margin for plastic/burned-in parts.
- Additional studies on other processes and packaging technologies should be performed to keep pace with the state-of-the art.

Source of Burn-In/Total Dose Effects

- Test Structure Studies
- Failure Analysis
- Burn-In Bias Variations
- Alternate Materials
  - Package Compositions
  - Processes
  - Technologies
- Delamination Not Likely

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ADDENDUM TO DAY 1
HONEYWELL PRESENTATION

COMPARISON OF NATIONAL VS HONEYWELL ANALYSIS METHODS

HONEYWELL FIELD RELIABILITY EXPERIENCE

NATIONAL VS HONEYWELL

- Purpose - "...Express a view of the Honeywell Raw Data...".

- Purpose - "...describe, compare...field reliability experience for plastic Vs hermetic microcircuits.

NATIONAL VS HONEYWELL

- Focuses on the variability between LRU's.

- Accepts variability as real world situation and statistically combines all data sources to draw conclusions.

NATIONAL VS HONEYWELL

- Gives equal weighting to data sources irrespective of sample size.
- Assumes predicted failure rates are equal within each category (Dig. SSI/MSI, Mem./LSI, Linear)

- Combines all data sources using chi^2 distribution at a 50% confidence level.
- Data factored to account for difference in predicted failure rates.

NATIONAL VS HONEYWELL

PEM./CERAMIC FAILURE RATE RATIOS

NS[1]	Device Grouping	HI
0.63	Digital SSI/MSI	0.50
0.72	Memory/LSI	0.44
3.6	Linear	3.0

1) W/O Statistical analysis & predicted failure rate factoring